VOT 74256

AN INTELLIGENT AND EASY HOME/OFFICE SYSTEM USING ARTIFICIAL INTELLIGENT TECHNIQUES

(RUMAH/PEJABAT MESRA DAN PINTAR MENGGUNAKAN KAEDAH KEPINTARAN BUATAN)

MOHAMAD SHUKRI B. ZAINAL ABIDIN
PROF. DR. MARZUKI B. KHALID
PROF. MADYA DR. RUBIYAH BT. YUSUF

PUSAT KECERDIKAN BUATAN DAN ROBOTIK (CAIRO)
FAKULTI KEJURUTERAAN ELEKTRIK
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BORANG PENGESAHAN
LAPORAN AKHIR PENYELIDIKAN

TAJUK PROJEK: **DESIGN AND DEVELOPMENT OF INTELLIGENT AND EASY HOME/OFFICE SYSTEM**

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(HURUF BESAR)

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Abstract

DESIGN AND DEVELOPMENT OF INTELLIGENT AND EASY HOME/OFFICE SYSTEM

(Keywords: Intelligent and Easy Home/Office System, I-Home, Web-based control System, Artificial Intelligent, Fuzzy logic, Neural Network)

An Intelligent Home (I-Home) System is envisioned as the by-product of pervasive computing and the availability of smart computer technology which making human interaction with the system a better home life experience. By the year 2020, home activities in Malaysia will be heavily influenced by interactive information and smart control systems. I-Home can provide homeowner a smart environment that monitor and control household functions. It can provide a gateway to communicate with the outside world through web-based system incorporated into the home. Using a web based control system, homeowner can quickly look into home to see live video and control lighting. It anticipates forecasted weather, thief prevention and utility costs.

Therefore the objectives of Intelligent Home System are comprises to two main objectives. The first objective is to develop master software based on Artificial Intelligent (AI) technique which is capable of integrating remote control and monitoring appliances and devices via the internet and the second objective is to design an intelligent sensor system using fuzzy logic and neural network to overcome false alarms occurrence as well as to provide home automation. The major phases of the research involves the development of intelligent sensoring system using AI techniques, development of home automation control, design and development of intelligent master list software, develop the control and communication protocols and development of integration module. The final phase is design and implementation of a prototype of the intelligent home system.

The prototype develops in CAIRO premises shows the ability of computer and communication technology in building the automated home system that function autonomously by using artificial intelligent engine. Results proof that combination of fuzzy logic and neural network can improve the controller performance with less human dependence.

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Abstrak

RUMAH/PEJABAT MESRA DAN PINTAR MENGGUNAKAN KAEDAH KEPINTARAN BUATAN

(Katakunci: Rumah Pinter, Pejabat Pintar, Applikasi web, Kepintaran buatan, logic fuzzy, rangkaian neural)

Sistem Rumah Pintar (I-Home) adalah satu produk berteknologi tinggi yang berasaskan kepada sistem komputer yang membolehkan manusia berinteraksi dengan sistem tersebut dengan lebih berkesan. Menjelang tahun 2020, aktiviti di rumah kediaman akan dipengaruhi oleh maklumat-maklumat secara interaktif dan sistem kawalan yang cekap. Sistem Rumah Pintar akan memberi pengguna persekitaran yang cekap dimana ia boleh memantau dan mengawal fungsi setiap perkakasan rumah. Ia juga menyediakan saluran komunikasi kepada dunia luar melalui laman web dan internet. Melalui sistem kawalan berasaskan lama web ini, pengguna juga dapat melihat persekitaran rumah mereka secara langsung melalui video atau mengawal lampu. Malumat lain seperti ramalan kajicuaca, penggera kecurian dan kos utiliti juga boleh diperolehi dengan cepat.

Oleh yang demikian, objektif rumah pintar ini terdiri daripada dua. Objektif pertama adalah untuk membangunkan perisian utama berdasarkan kepada kaedah kecerdikan buatan yang berupaya mengintegrasi sistem kawalan yang jauh dan pemantauan peranti-peranti dan peralatan-peralatan menggunakan internet. Objektif yang kedua adalah untuk membangunkan sistem penderia pintar menggunakan logik fuzzy dan rangkaian neural untuk mengatasi masalah amaran-amaran palsu dan juga menyediakan sistem automasi kediaman. Fasa utama dalam kajian ini termasuk membangunkan sistem penderia pintar menggunakan kaedah kepintaran buatan, membangunkan sistem automasi kediaman, rekabentuk dan pembangunan perisian senarai utama pintar, rekabentuk dan pembangunan protokol komunikasi dan pembangunan modul bersepadu. Fasa terakhir adalah pembangunan prototaip sistem rumah pintar tersebut.

Prototaip yang dibangunkan di premis CAIRO menunjukkan hasil dan keupayaan sistem komputer dan teknologi komunikasi dalam membina sistem automasi kediaman yang boleh berfungsi secara automatik menggunakan fungsi kecerdikan buatan. Keputusan ini menunjukkan kombinasi logik fuzzy dan rangkaian neural boleh meningkatkan prestasi dan kecekapan sistem kawalan tersebut dengan bantuan manusia yang minimum.

Penyelidik Utama:

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CHAPTER 1

INTRODUCTION

1.1 Project Information

Project Title	**:**	Intelligent and Easy Home/Office System Using Artificial Intelligent Techniques
IRPA Vote No	**:**	74256
Project Leader	**:**	Mohamad Shukri b. Zainal Abidin
Project Team	**:**	Prof. Dr. Marzuki b. Khalid Prof. Dr. Rubiyah bt. Yusof Mohd Fairul Zamzuri b. Che Sayuti Hanafi b Hassan
Total Grant	**:**	RM 187,540.57

1.2 Project Background

One of the benefits of the rapid evolution of information technology has been the development of system that can measure, evaluate, and respond to change. One of the outcomes the advancement in this technology is the much talk about intelligent home system. Basically an intelligent home system is the incorporation of information technology and communication system to make house more secure, easy to live, productive and cost effective. Various product of intelligent home system has emerged over the past years. Most of the product centers around using the facilities provided by the internet, mobile phones, telephones and various mean of communication to control some application in the houses remotely, such as lighting television etc. Also most intelligent home system also are equipped with surveillance cameras for home owners to check their home visually using web browser. In Malaysia a company called I-Berhad has come up with an intelligent home system which has the capabilities as described above.

Despite the capabilities provided by the existing system, there are many more areas which need to be improved and researched upon to be able to have a more intelligent home system which would make it safer, easier to live in, energy saving etc. in fact Microsoft is extensively doing research on intelligent home system which is called easy living system where additional features such as acquiring and learning the behaviors of the owners to enable the device to be automatically switched on and off for the convenience of the house owners

One of the features that are lacking in the current intelligent home system is an intelligent device which would be able to differentiate between false alarm and real alarm. Also integration between the appliances is still lacking in some of the intelligent home system. Such as when an alarm occurs because of the fire, then at least one automatic door should be unlocked. False alarm is known to be a nuisance to a lot of home owners to the extend that some simply choose to disable their alarm system. False alarm also causes a lot of wastage on man-hours. In view of these facts, this project also look into the area of a more intelligent based sensoring system using some AI technique such as fuzzy logic or neural network to add on the current intelligent home automation system. Having a more sensoring system would be help in reducing the occurrence of false alarm.

An intelligent sensoring system can also be used to make life easier for house owners as well as a power savings and cost saving devices. For example in the hot day the intelligent sensoring system will switch on the fan at the higher speed so that the house owners will be cooler and reduce the speed as the temperature goes down. If the house owner leaves the room, the fan or light will automatically be switched off. Thus saving electricity consumption. This project will also consist of developing more intelligent software for the master list manager which can integrate the devices and appliances in a house or office. This would ensure that an appropriate action would be taken for a certain occurrence of events.

1.3 Project Objectives

The main objective of this project is to design an intelligent home automation system that can provide home and office owners with an integrated environment, intelligent devices, ease-of-use and safety. This objective can be categorized into two main parts which are:

i. To develop master software based on Artificial Intelligent (AI) techniques which are capable of integrated remote control and monitoring of appliances and devices via the internet, record events and providing security.

ii. To design intelligent sensoring system using AI techniques such as fuzzy logic and neural network to overcome false alarms occurrence as well as to provide easy living and power savings.

1.4 Report Layout

Chapter 1 describes on the introduction and brief information of the project. As explained in the sub topic above, which is topic 1.3, this chapter briefly describe on the project objectives, which is the main objectives of developing of I-Home System. The objectives are generally divided into two main categories which involve the application of artificial intelligent techniques; fuzzy logic and neural network in achieving the target.

Chapter 2 describes on the brief definition of I-Home System and the literature review, which explain the information and collection of materials necessary for this research project. In the definition of I-Home System, this section explains the significant of I-Home and the beauty of this system. The literature review part includes introduction and initial knowledge of artificial intelligence, fuzzy logic, home appliances and fuzzy logic and neural network. These knowledge are the main idea and sources for this project.

Chapter 3 describes on the research methodology which includes the introduction and significant of research methodology in developing a system. This section explains the 4 phases involves in this project which are Phase 1; Development of Intelligent Sensoring Technique, Phase 2; Intelligent Master List Software Development, Phase 3; Communication Protocol for Integration and Phase 4; Development of Prototype System.

Chapter 4 explains the system development which involves two main phases; prototyping and implementation. In this section, the prototyping stage explains on the processes, equipments, materials and techniques needed for this system. The prototype is done for Pc-based Automation System, Pc-based Surveillance System, Basic Biometric Verification (fingerprint), Pc-based SCADA System and the testing for suitable Ethernet-based embedded. The second phase is implementation, which explains on the devices and customized software required for this system.

Chapter 5 is conclusions, describes on achievement of the main objectives as mentioned in the chapter 1. The I-Home System is met the objectives which are to develop a master software that capable of integrated remote control and monitoring of appliances and devices via the internet, record events and providing security. The second objectives also successfully achieved which is to design and intelligent sensoring system to overcome false alarm occurrence as well as to provide easy living and power saving.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Until today, there are many researches done on intelligent home. There are researches or projects done on automated smart home but smart home need input from user most of the time. At the same time, there are projects done using artificial intelligent which included either using the fuzzy logic or neural network.

The interest of industrial labs in smart home and networked appliance technologies is evidenced by the creation of Jini, Bluetooth, and SIP standards. Projects at Stanford and Xerox PARC are developing intelligent workspaces that provide an interactive, platform-independent interface to a sophisticated set of display and note-taking tools. Microsoft's Easy Living project uses an actual smart home prototype to test technologies for location tracking and networked devices. The Cisco Internet Home, the Verizon Connected Family project, and the E2 Home offer impressive demonstrations of device communication and home networking.

2.2 The Definition of Artificial Intelligence

Artificial intelligence (also known as machine) is intelligence exhibited by any manufactured (artificial) system [*Leslie,S., University of Stirling*].

Intelligence is a capability of a system to achieve a goal or sustain desired behavior under conditions of uncertainty. Intelligence systems have to cope with the sources of uncertainty like the occurrence of unexpected events-such as an unpredictable changes in the world in which the systems operates, and incomplete, inconsistent or unreliable information available to the system for the purpose of deciding what to do next [*Christos Stergiou and Dimitrios Siganos*].

It is important to contrast between intelligent systems, for example, systems that can make decisions under uncertainty, with the systems that are programmed to make only deterministic decisions. Data processing systems, conventional robots, production lines and computer controlled machines tools are examples of such non-intelligent systems.

Intelligent systems exhibit intelligent behavior. Intelligent behavior is exhibited by artifacts and biological systems capable of achieving specified goals or sustaining desired behavior under conditions of uncertainty even in poor structured environments [*Lou Mendelsohn, president of' Market Technologies Corporation*]. Such environments are environments in which variable characteristics are not measurable, where several characteristics change simultaneously and in unexpected ways and where it is not possible to decide in advance how the system should respond to every combination of events. Some characteristics of intelligent behavior are: adaptability, learning, goal-seeking, self-improvement and reproduction.

Many other useful technological systems have been built using AI techniques. Some examples include:

- Fuzzy logic, a technique for reasoning under uncertainty, has been widely used in industrial control systems.
- Expert systems are being used to some extent industrially.
- Machine translation systems such as SYSTRAN are widely used, although results are not yet comparable with human translators.
- Neural networks have been used for a wide variety of tasks, from intrusion detection systems to computer games.
- Optical character recognition systems can translate arbitrary typewritten European script into text.
- Handwriting recognition is used in millions of personal digital assistants.
- Speech recognition is commercially available and is widely deployed.

2.2.1 Knowledge Theory

To be intelligent, it requires knowledge and reasoning skills. Intelligent behavior implies the linking of these two together and hence being able to deduce facts that are not explicit in the knowledge and produce sensible reactions to these facts. In humans there is a consciousness that enables us to understand concepts such as what and why, that is intentionality. With this ability we are able to make reasoned judgments and act accordingly. Of course the "reason" within our decisions is often subjective (and in the same way, our definition of intelligent behavior is largely subjective). So what forms of reasoning are there? The three main types are deduction, abduction and induction.

The second requirement for intelligent behavior is the knowledge itself. It is impossible to reason conclusions from knowledge if there is no knowledge. So if we put some facts into a computer system, use a reasoning program into action and we in theory have an intelligent machine! The reality is that many of these A.I. structures will work well in simple "toy" domains but once they are presented with real world domain problems and give real world values they suddenly begin to have problems. The problem is that they don't have enough knowledge about the domain and so can't respond to it. If we attempt to simply solve this problem by stuffing more information into the system we quickly come across the problem of speed. The specific piece of information in the database of knowledge cannot be accessed fast enough for a reasonable response using simple search techniques.

One of the major keys to AI then is being able to store knowledge in an efficient fashion and in such a way that it is possible to compose programs that can access it in a reasonable time. In an ideal world all the knowledge in the world would be incorporated into a system, but this leaves obvious problems. There are no obvious solutions but a number of methods have been proposed that look at knowledge representation like semantic nets, conceptual graphs, frames, first order predicate calculus and rules but there is not time to go into these topics in the confines of this essay.

2.2.2 Expert Systems

An expert system is a class of computer programs developed by researchers in artificial intelligence during the 1970s and applied commercially throughout the 1980s. In essence, they are programs made up of a set of rules that analyze information (usually supplied by the user of the system) about a specific class of problems, as well as provide analysis of the problem(s), and, depending upon their design, a recommended course of user action in order to implement corrections.

Besides that, expert system also has its own knowledge base and inference rule. There is also another module called confidences which will not be covered since my project will only involve the surface part of an expert system.

Anyhow knowledge base is concerned with the representation chosen for the expert's knowledge declarations and with the inference engine used to process that knowledge. There are several characteristics known to be appropriate to a good inference technique. A good inference technique is independent of the problem domain. In order to realize the benefits of explanation, knowledge transparency, and reusability of the programs in a new problem domain, the inference engine must not contain domain specific expertise. Inference techniques may be specific to a particular task, such as diagnosis of hardware configuration. Other techniques may be committed only to a particular processing technique. Moreover, inference techniques are always specific to the knowledge structures. Successful examples of rule processing techniques are such as forward chaining and backward chaining.

To understand further on expert systems, an understanding of the inference rule concept is important. An inference rule is a statement that has two parts, an if-clause and a then-clause. An example of an inference rule is “if the temperature is hot, then let the fan spin faster.” An expert system's rule base is made up of many such inference rules. They are entered as separate rules and it is the inference engine that uses them together to draw conclusions. Because each rule is a unit, rules may be deleted or added without affecting other rules (though it should affect which conclusions are reached). One advantage of inference rules over traditional programming is that inference rules use reasoning which more closely resemble human reasoning. Thus, when a conclusion is drawn, it is possible to understand how this conclusion was reached. Furthermore, because the expert system uses knowledge in a form similar to the expert, it may be easier to retrieve this information from the expert.

There are two main methods of reasoning when using inference rules: backward chaining and forward chaining. Forward chaining starts with the data available and uses the inference rules to conclude more data until a desired goal is reached. An inference engine using forward chaining searches the inference rules until it finds one in which the if-clause is known to be true. It then concludes the then-clause and adds this information to its data. It would continue to do this until a goal is reached. Because the data available determines which inference rules are used, this method is also called `data driven. Backward chaining starts with a list of goals and works backwards to see if there is data which will allow it to conclude any of these goals. An inference engine using backward chaining would search the inference rules until it finds one which has a then-clause that matches a desired goal. If the if-clause of that inference rule is not known to be true, then it is added to the list of goals.

2.2.3 Fuzzy Logic

Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth which the truth values between completely true and completely false. Boolean logic says that something is either on or off, true or false. You are either sleeping or awake. However what about the time in-between, for example the time in-between sleep and a full state of consciousness. When sitting down for a meal, the meal is not just there or not there, there is a continuous period of it being eaten and each period can be broken down further into more stages of being eaten or not eaten. Hence an idea was introduced as a means to model the uncertainty of natural language.

Actually it is better to regard fuzzy theory as the process of fuzzification as a methodology to generalize any specific theory from a crisp (discrete) to a continuous (fuzzy) form rather than fuzzy theory as a single theory. Thus recently researchers have also introduced fuzzy calculus, fuzzy differential equations, and so on. Fuzzy logic is used directly in very few applications. The Sony PalmTop apparently uses a fuzzy logic decision tree algorithm to perform handwritten (well, computer lightpen) Kanji character recognition. Most applications of fuzzy logic use it as the underlying logic system for fuzzy expert systems. Fuzzy logic and neural networks have been implemented together in recent times and they were even used to control a helicopter with a missing rotor blade. The point being that this could be done quickly enough by a computer but not by a pilot even though initially the program had to be trained by a pilot.

Fuzzy logic is widely used in controller nowadays. Figure 2.1 shows the typical fuzzy controller diagram. From the diagram a typical fuzzy controller can be divided into four major parts which consists of fuzzification, inference engine, knowledge base and defuzzification. In the fuzzification part, input/output signals are converted into a number of fuzzy represented values. Then these fuzzified data will be inferred to the knowledge base. After the inference is done then a defuzzifier is needed to defuzzify the data back to crisp data.

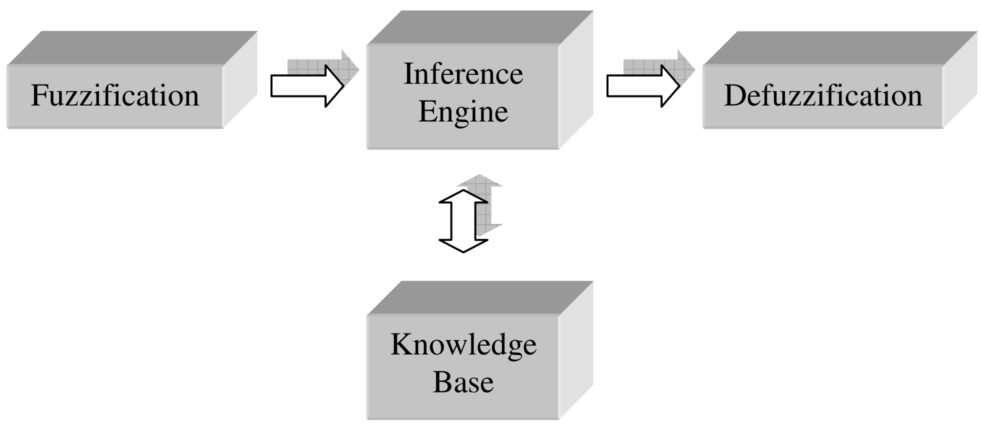


Figure 2.1: A typical fuzzy controller diagram

2.3 Home Automation Project

Below are some of the projects done in smart home and home automation field that inspired and motivated this research to develop a new design and concept of Intelligent and Home Automation system

2.3.1 Intelligent Home Automation

Work by Khoo (2004), has developed the intelligent home using fuzzy logic in artificial intelligent. Fuzzy logic is build base on rules created. If…Else statement is used in this project where the system able to make decision to execute the desired action base on the rules in rules based.

In the project, a fuzzy controller is used to control the brightness of the light. The source code for the fuzzy logics is developed in the PC. Hence the RS232 controller board is used to transmit and receive data from the PC to the sensors or vice-versa. The rule base, values and data needed for the fuzzy controller is displayed to let the user view how the fuzzy controller works. The system develops able to choose the brightness and level of fan desired by inferred the rules based in fuzzy logic.

2.3.2 Smart Home Project

The smart home project started in 1999 with the conversion of a laboratory space into a smart living room. The smart home is the base for the eHome research project, and it is primarily used as a testing and demonstration environment at Tampere University of Technology. The smart home was built in 2002 to resemble a normal $69m^2$ flat with a bedroom, living room, kitchen, sauna and bathroom. Normal household items and furniture has been installed to make the space seem comfortable and familiar. The home is used for testing prototypes, usability testing, measurements and product demonstrations.

The entrance to the smart home is a motorized door with an electric lock and a fingerprint scanner. Approved users can open the door by placing their thumb on the scanner. A welcoming message will sound from the speaker above the door and the door will open. On the inside, a control panel can be used to control the lights in the apartment. When coming home, all lights can be turned on with a single key press. Likewise when leaving the home there are no worries about forgetting something when all lights can be turned off at once.

The function of the bedroom is to create a relaxing environment for resting and sleeping. A big screen on the wall allows projection of pleasant images or creation of a relaxing environment while adjustable lights and window shades can provide a pleasant wakeup in the morning.

The living room can be used for social functions as well as entertainment. Another big screen and a fully equipped home theater enable maximum enjoyment of movies and music. Artificial and natural light can be adjusted to create a pleasant atmosphere when desired. A big couch provides a good place for sitting and reading the daily news from the wireless tablet PC.

Behind the living room is the dining area, for dining and social intercourse. Here are also some of the home's plants, which can be monitored. The system can alert the inhabitants in case of low water, temperature or light levels.

The kitchen provides everyday cooking facilities, adjustable lights and normal home appliances. Recipes can be viewed online from the tablet PC.

The bathroom and sauna are the same as in any normal apartment. In addition to this, music can be directed to the speaker in the bathroom so the resident can listen to their favorite tunes while sitting in the sauna. The sauna temperature can also be monitored from anywhere in the apartment, along with a notice from the computer when the desired temperature has been reached.

2.3.3 The Adaptive Home

The aim of this project is to develop an adaptive control system that can infer appropriate rules of operation for home comfort systems based on the lifestyle of the inhabitants and energy conservation goals. Recent research in this project has demonstrated the potential of neural networks for intelligent control.

The control for the adaptive home is tailored to a particular home and family, and updated as the family's lifestyle changes. Tackling the programming task is far beyond the capabilities and interest of typical home inhabitants. Indeed, even rudimentary forms of regulation, such as operating a set back thermostat, are inordinately difficult for people. The alternative of hiring professional technicians to update programs as necessary is used in some commercial systems, but is costly and inconvenient. Partly is due to the difficulties in programming.

In contrast to standard computerized homes that can be programmed to perform various functions, the aim of this project is to develop a home that essentially programs itself by observing the lifestyle and desires of the inhabitants, and learning to anticipate and accommodate their needs. The system developed controls basic residential comfort systems, HVAC (heating, ventilation, and air conditioning), water heater, and interior lighting. The system monitors the environment, observes the actions taken by occupants (e.g., turning up the thermostat; turning on a particular configuration of lights), and it attempts to infer patterns in the environment that predict these actions. If the actions can be reliably anticipated, the system can perform the actions automatically, freeing the occupants from manual control of the home. A secondary consideration of the system is to conserve energy resources, when possible.

A prototype system is constructed in an actual residence. The home laboratory is equipped with an array of over 75 sensors which provide information about the environmental conditions monitored, temperature, ambient light levels, sound, motion, door and window openings and actuators to control the furnace, space heaters, water heater, lighting units, and ceiling fans.

Control systems in the residence are based on neural network reinforcement learning and prediction techniques. Neural networks are artificial learning devices inspired by the workings of the human brain. These networks are made up of hundreds or thousands of simple neuron-like processing units, which, through their interactions, achieve complex behaviors, and have the ability to learn from experience.

The system can predict the time for occupants returning home and determine when to start heating the house so that a comfortable temperature is reached by the time the occupants arrive; detecting statistical patterns of water usage, such that hot water is seldom if ever used in the middle of the day on weekdays, allowing the water heater to shut off at those times; inferring where the occupant is and in what activities the occupant is engaged, perhaps he is reading at the kitchen table and controlling lighting patterns and intensities accordingly, even anticipating which rooms are about to be entered and turning on the lights before the room becomes occupied.

By inferring occupancy and usage patterns in the home, the system can make life more comfortable and conserve energy at the same time.

2.3.4 The MavHome Project (Managing An Intelligent Versatile Home)

The MavHome Smart Home project is a multi-disciplinary research project at the University of Texas at Arlington (UTA) focused on the creation of an intelligent and versatile home environment. The goal of this project is to create a home that acts as a rational agent, perceiving the state of the home through sensors and acting upon the environment through effectors. The agent acts in a way to maximize its goal, which is a function that maximizes comfort and productivity of its inhabitants, minimizes cost, and ensures security. In order to achieve these goals, the house must be able to reason about and adapt to its numerous, heterogeneous resources (e.g., devices, sensors, networks) and its inhabitants.

UTA represents an excellent site to perform such an aggressive project. The Dallas / Fort Worth metroplex currently represents one of the highest concentrations of high-tech industries in the nation, and is the ``Telecom Corridor'' of Texas. Many companies from this area are partnering with this highly visible project. In addition, the PIs conduct research and have established successful centers and labs in the critical technology areas for smart homes. This project will be a focal point for cross-disciplinary research with tangible outcomes. An actual smart home on the UTA campus is to develop and demonstrate the technologies.

The MavHome architecture is a hierarchy of rational agents which cooperate to meet the goals of the overall home. The technologies within each agent are separated into four cooperating layers. The Decision layer selects actions for the agent to execute based on information supplied from other layers. The Information layer gathers, stores, and generates knowledge useful for decision making. The Communication layer contains software to format and route information between agents, between users and the house, and between the house and external resources. The physical layer the basic hardware within the house including individual devices, transducers, and network hardware. Because the architecture is hierarchical, the Physical layer may actually represent another agent in the hierarchy. Each of the layers contains a number of technology components that will be addressed in this project.

Perception is a bottom-up process. Sensors monitor the environment (e.g., lawn moisture level) and, if necessary, transmit the information to another agent through the Communication layer. The database records the information in the Information layer, updates its learned concepts and predictions accordingly, and alerts the Decision layer of the presence of new data. During action execution, information flows top down. The Decision layer selects an action (e.g., run the sprinklers) and relates the decision to the

Information layer. After updating the database, the Communication layer routes the action to the appropriate effector to execute. If the effector is actually another agent, the agent receives the command through its effector as perceived information and must decide upon the best method of executing the desired action. A specialized interface agent provides interaction capabilities with users and with external resources such as the Internet.

2.4 Conclusions

From the previous research and projects, it is concluded that the intelligent home desired in the society today is an environment that is envisioned as the by-product of pervasive computing and the availability of smart computer technology, making human interaction with the system a better home life experiences.

The system provide home owner a smart environment where he or she can monitor and has a complete control over the household functions, access, security, automation, energy savings which also incorporates and intelligent system. Controls over these core elements provides the foundation of a total smart home/office solution, giving the resident of the property combined benefits of security, convenience, lifestyle enhancement and energy saving benefits simultaneously.

The system must also able to learn and adapt to the inhabitant behavior. The project existences have played an important role in build up the idea of the whole project. From the projects, a different between the automation house that do not have the ability to learn and also the adaptive house that able to adapt to the inhabitant lifestyle is shown.

CHAPTER 3

METHODOLOGY AND APPROACH

3.1 Project Methodology

The approach for planning and guiding the project from start to finish is considered as the most significant part of the project development. It is because, in the final analysis, the most important factor for the success of a project is how closely the particular plan was followed.

This project is divided into four phases. It involves initial feasibility study through maintenance of the completed application. The phases of development are:

i. Phase 1 : Development of Intelligent and Sensoring Techniques
ii. Phase 2 : Intelligent Master List Software Development
iii. Phase 3 : Communication Protocol for Integration
iv. Phase 4 : Development of Prototype System

The following discussion, will explain the phases scope and development work in detail.

3.1.1 Phase 1: Development of Intelligent Sensoring Techniques

3.1.1.1 Literature Review

This part covers on current trends and technology of home automation system, which comprises security system, burglar alarm, fire alarm, surveillance camera and home appliances control are among the initial studies for this project. Features of home automation control, which include the database management of event logged, time scheduled event and also personalized condition execution are also a necessary part for this project. This also covers on the studies of the various sensors and their application and an existing Artificial Intelligence techniques and their application in intelligent sensors. This project also requires information on various communication mediums including the state of the art technology in the internet and World Wide Web.

3.1.1.2 Software Development

In this part, smart features are added into various sensors such as motion sensor, smoke detection sensor, temperature sensor and heat sensors. For this task, Artificial Intelligent techniques such as fuzzy logic and neural network are used.

3.1.2 Phase 2 : Intelligent Master List Software Development

3.1.2.1 Development of an Intelligent Integrated Monitoring and Control

System

In order to control the devices more intelligently, the master list manager is incorporated with some AI technique. The software is intelligent enough such that it can perform integrated control of all devices in the houses or offices.

3.1.3 Phase 3 : Communication Protocols for Integration

3.1.3.1 Development of the Control Protocols for Integration

In this part, the software development for the control protocols is carried out to integrate the master list manager and various available sensors and devices.

3.1.4 Phase 4 : Development of Prototype System At CAIRO Premise in UTM

The prototype of the intelligent home automation system are designed and developed. At this stage, various components are used as the sensors and actuators to the system. The process include: -

i. Configuring the Main Controller
ii. Installation of Surveillance Camera
iii. Installation of Sensors
iv. Installation of Actuators

3.1.4.1 Configuring the Main Controller

The core or the backbone for the intelligent home automation system is a standard PC equipped with the multimedia and video capturing capability. The PC is internet ready. The developed software engine from phase 3 will be running as the main controller to manage and integrated the whole system.

3.1.4.2 Installation of Surveillance Camera

CMOS cameras are installed and wired to the main controller to allow user to view the scene inside the labs or it's surrounding. This selected area is categorized as critical and need to be monitored continuously such as the main entrance and office. The system is configured to captured and stored images at predetermined time laps. The current and history images can be viewed through internet web browser at PC.

3.1.4.3 Installation of Sensors

The labs and offices are wired with sensors such as door limit switch, light barrier, passive infrared (PIR) sensor, vibration and break glass sensor to detect the presence of human at any place inside the premises. Sensors such as smoke sensors, heat sensor, light dependent sensor (LDR), temperature sensor are used to collect indoor data to provide the main intelligent system detail information on the current state of environment and weather condition. This data also stored for further analysis and decision for the core engine. But the most important use of these sensors is to detect and alarm the user upon dangerous event such as fire or burglar.

3.1.4.4 Installation of Actuators

A part from sensors the premise is also wired with actuator such as magnetic solenoid, magnetic relays, speaker and siren. This is to prompt the intelligent home automation system to respond with the user physically. In event such as fire, the system will automatically unlock the backdoor and light up the emergency bulb while sounding alarm. The system can also turn on the light at any predetermined period, or upon detection of motion or human presence, or switch it off when nobody is detected. The relays also will enable the user to get control of their home appliances.

CHAPTER 4

SYSTEM DEVELOPMENT

4.1 Background

The project is envisioned as the by-product of pervasive computing and the availability of smart computer technology, making human interaction with the system a better home life experiences. The system can provide home owner a smart environment that can monitor and control household functions.

The system gives complete control over the controls, access, security, automation, energy savings and also incorporates and intelligent system. Controls over these core elements provides the foundation of a total smart home/office solution, giving the resident of the property combined benefits of security, convenience, lifestyle enhancement and energy saving benefits simultaneously.

The beauty of the system is the fully flexible modular system which can be installed in both new and existing homes and offices. Plus, it is an Ethernet-based system which is rapidly developed and supported nowadays. It is always easy to plan, expand or change and installed. Status of given function can be controlled and ready anywhere on the network by several components simultaneously and it is easy to add new components to a function address or re-route a function.

The possibility of using existing network system can facilitate the installation instantly. At the centre of the system is the Master Controller System which is a central unit that contains a micro-controller that performs the desired function. The controller can be located anywhere in the installation and each device (switch thermostat or sensor) is configured just from the web. Most of the existing security products (locks, sensors and detectors) can be incorporated into the system. This system is exceptionally easy to install and configure and is based on reliable bus system. The flexibility of the System makes it more attractive than other systems and the fact it is a wired system gives it total reliability

4.2 Project Development

In system development process, there must be a few steps or phases that have to go through to ensure all the development process successfully completed. Otherwise, there might be some constraints or problems that may occur. There are two main phases that involved in the development of the system, which are:

i. First Phase : Prototyping
ii. Second Phase : Implementation

4.2.1 First Phase : Prototyping

The first phase involved with component selection and integration testing. Throughout this phase the processes, equipments, materials, technology and communication techniques that are required for this system are identified and tested. Most of the work here is to investigate the overall structure of system for reliability and easy of integration of the components to the main system. For the first phase, the prototyping of parts are done, which are:

i. Pc-based Automation System
ii. Pc-based Surveillance System
iii. Basic Biometric Verification (fingerprint)
iv. Pc-based SCADA System
v. Web-based SCADA System
vi. Testing for suitable Ethernet-based embedded

4.2.1.1 PC-Based Automation System

Master Controller system with Supervisory Control and Data Acquisition (SCADA) system has been developed using VB.Net language and object oriented. Master Controller System is the advanced central unit. Apart from control the automation system, it can perform various intelligent control and network functions. SCADA system is a central system that monitors and controls the devices through the Master Controller system. Pc-based automation developed has the features below: -

i. ADAM 6050/6017 I/O Modules
ii. MIFARE Card Reader
iii. SMS and GSM Modem
iv. Fingerprint Biometric Module
v. Encrypted TCP/IP communication module for remote control (by using the library from mentalis.org that use Microsoft digital certificate)

Below are Figures 4.1, 4.2, 4.3, 4.4 that show the interfaces of Master Controller system with SCADA system.

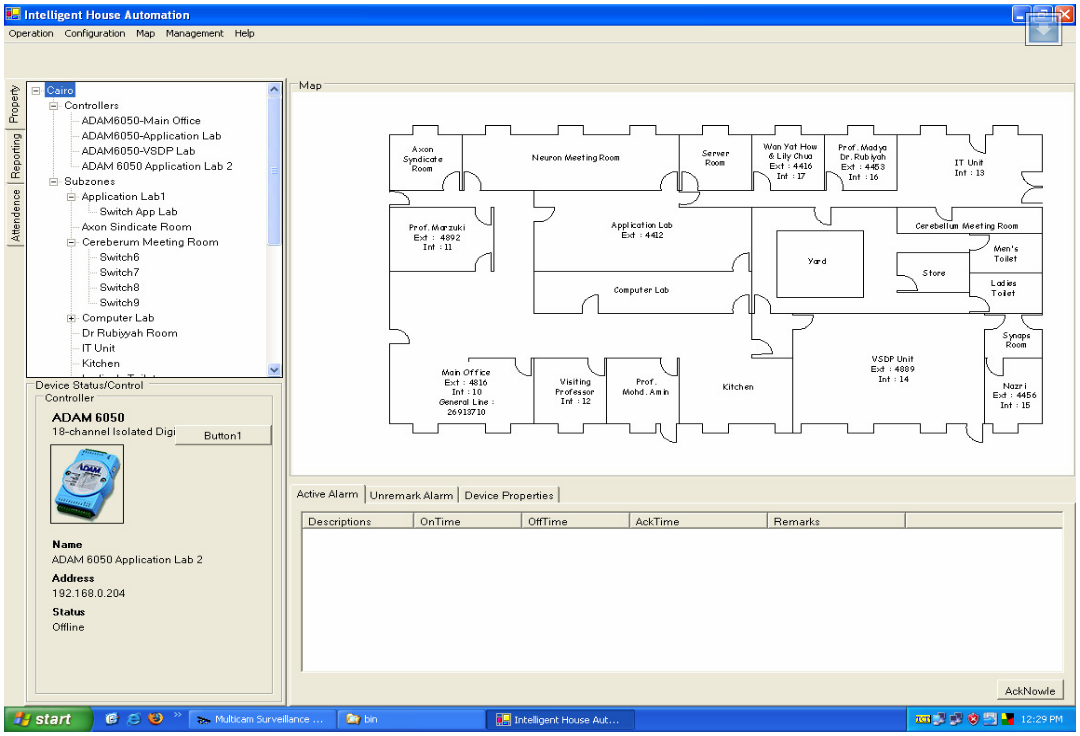


Figure 4.1: Main Interface of Pc-based

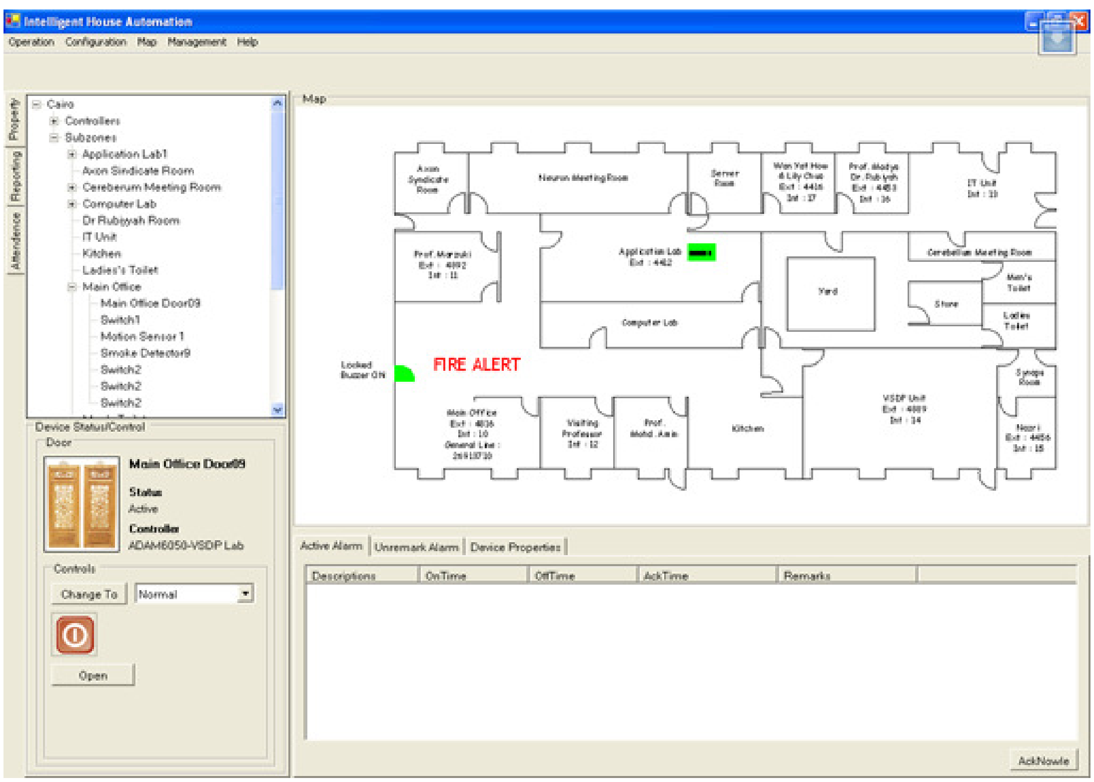


Figure 4.2: Interface of Door Control

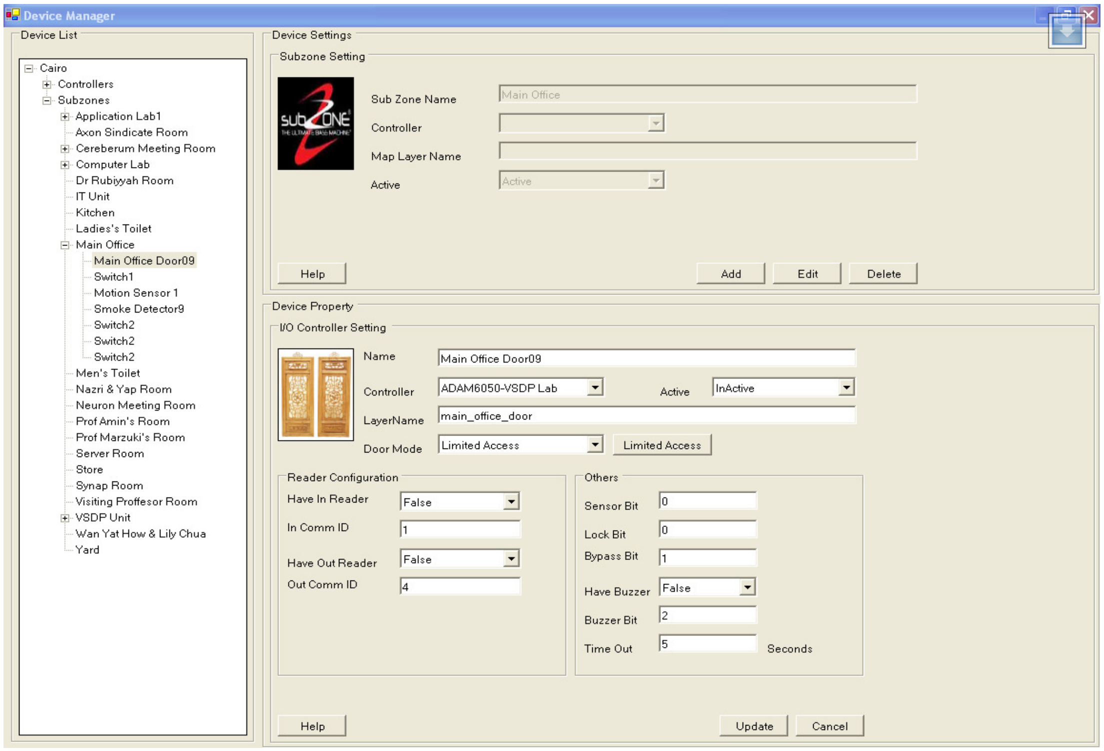


Figure 4.3: Interface of Door Control Setting

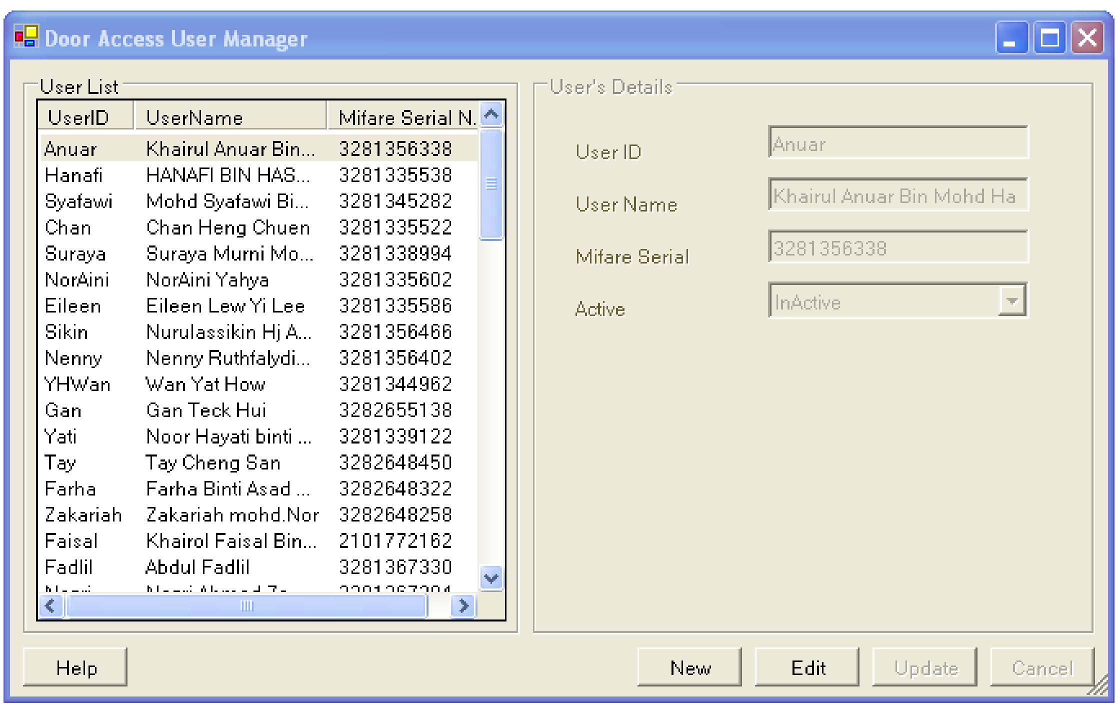


Figure 4.4: Lists of Door Access User

There are a few advantages and disadvantages using the Master Controller system and SCADA system. The advantages that is, it is a rapid and easy system development. Other than that it is also use AutoCAD drawing as a map that can pan and zoom. Another advantage of the system is multi layer that can has map, wiring drawing, piping, network cabling and etc. The disadvantages of from the pc-based are, the computer itself is high power consumption equipment with hard disk and fan that make their failure rate higher. The Windows operating system also is instable. Several layers of drawing for displaying different component and part are difficult to update when new hardware is added.

4.2.1.2 ADAM 6050/6017 Input and Output Modules

ADAM 6050 is an Ethernet digital input and output that has 12 digital input and 6 digital outputs whereas ADAM 6017 is an Ethernet analog input and output that has 12 analog input and 2 digital outputs. Unigram Data Protocol (UDP) is a multicast support. The problem of this module is the manufacturer supplied SDK is limited to MS Windows platform and it was slow. Therefore, the tasks are to re-implement the communication protocol for portability and better performance and also use ethereal (open source packet sniffer) to reverse engineer the protocol. The obtained results are the new protocol that has been redeveloped. The protocol is tested and used in programming written in several languages which are VB.Net, C#, C, PHP and it works better

Devices such as alarm and sensors are used to detect environment status. Most of the devices in the market use a contact-based as output. Some of the devices are motion sensor, smoke detector, door lock, flux sensor and vibration sensor and all of them use 12 Volt and connected to ADAM 6050 and ADAM 6017. The Figures 4.5 to 4.8 below shows the configuration panel modules for ADAM 6050 and ADAM 6017, the packet sniffer monitor software and the simulator/trainer used to test the modules.

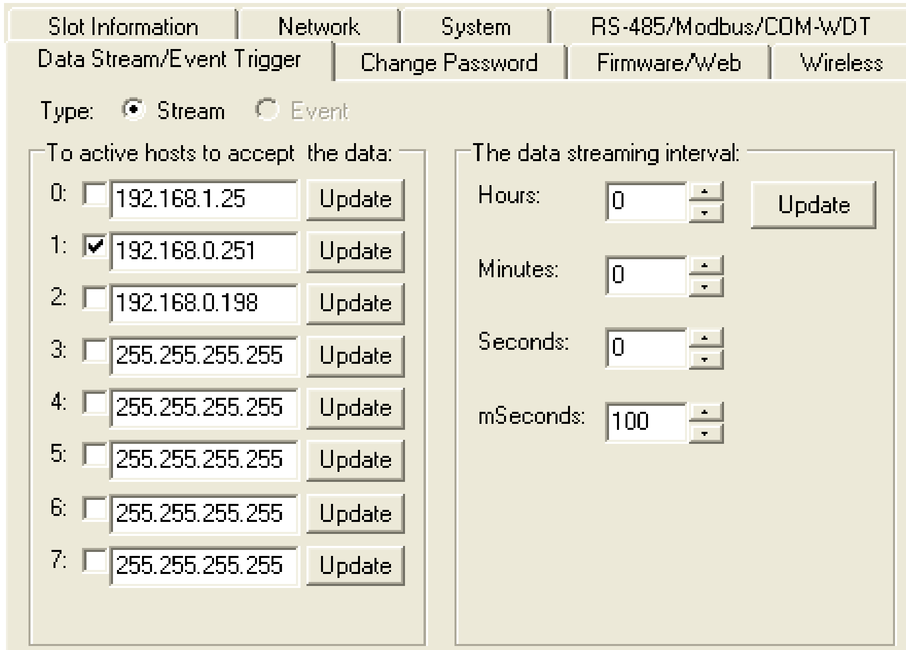


Figure 4.5: ADAM 6050/6017 Configuration

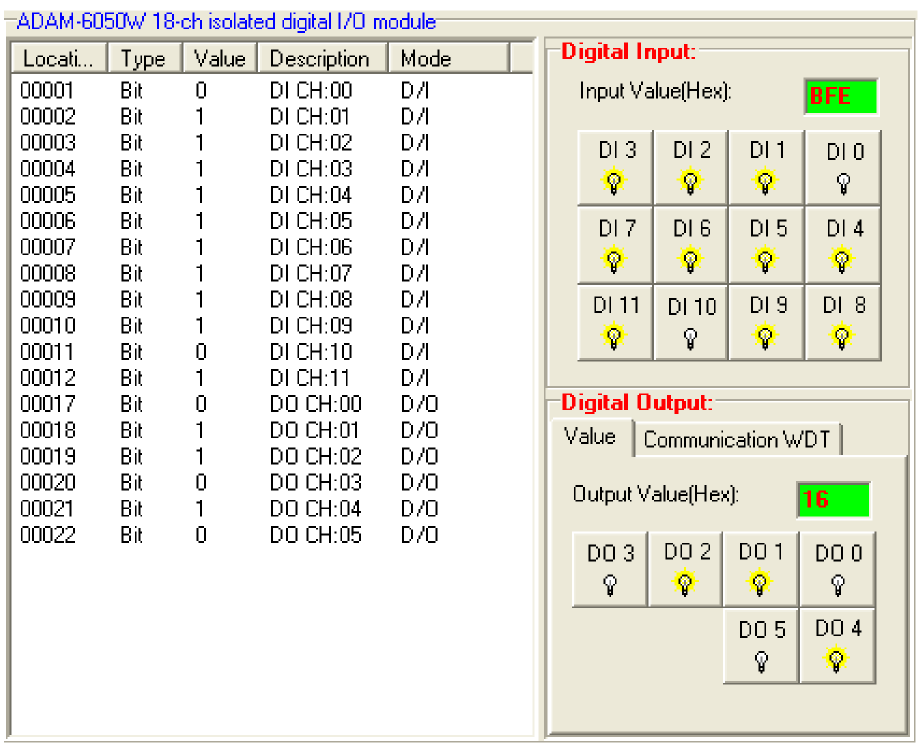


Figure 4.6: ADAM 6050/6017 Status Monitor

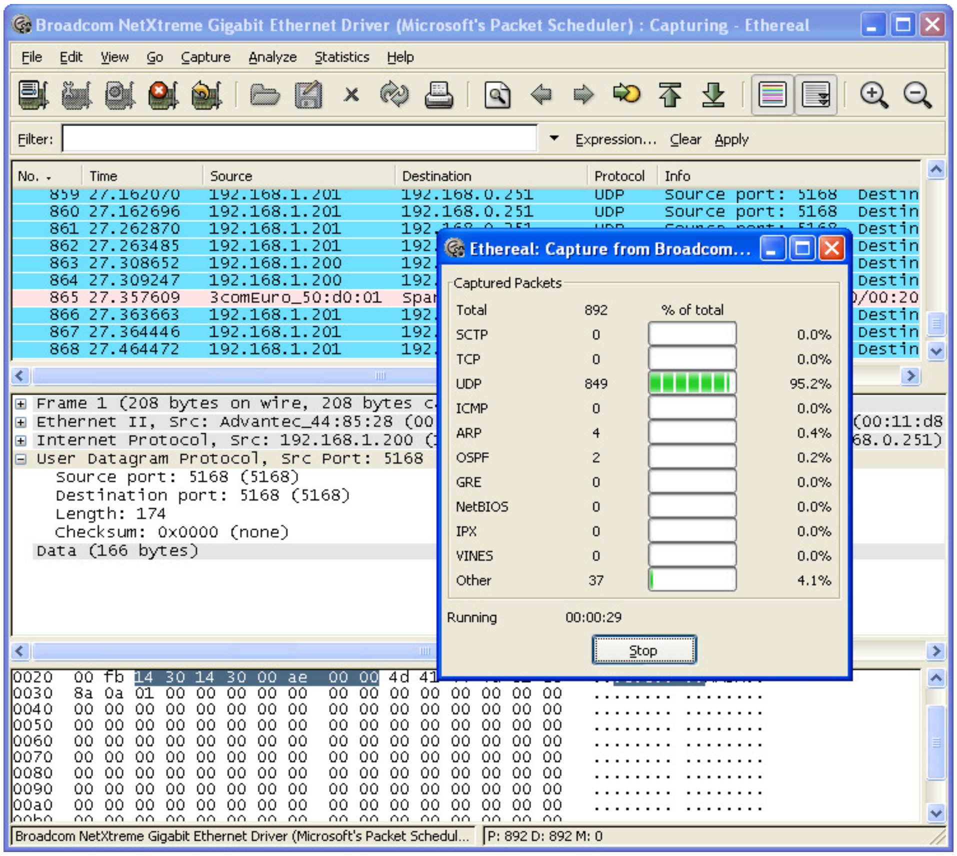


Figure 4.7: Packet Sniffer

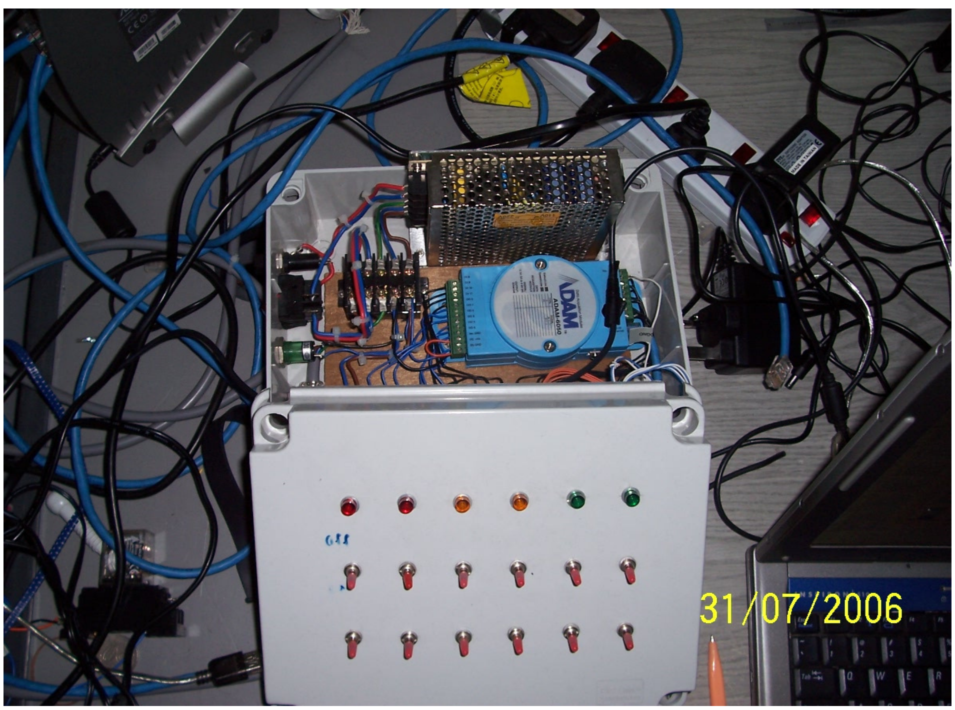
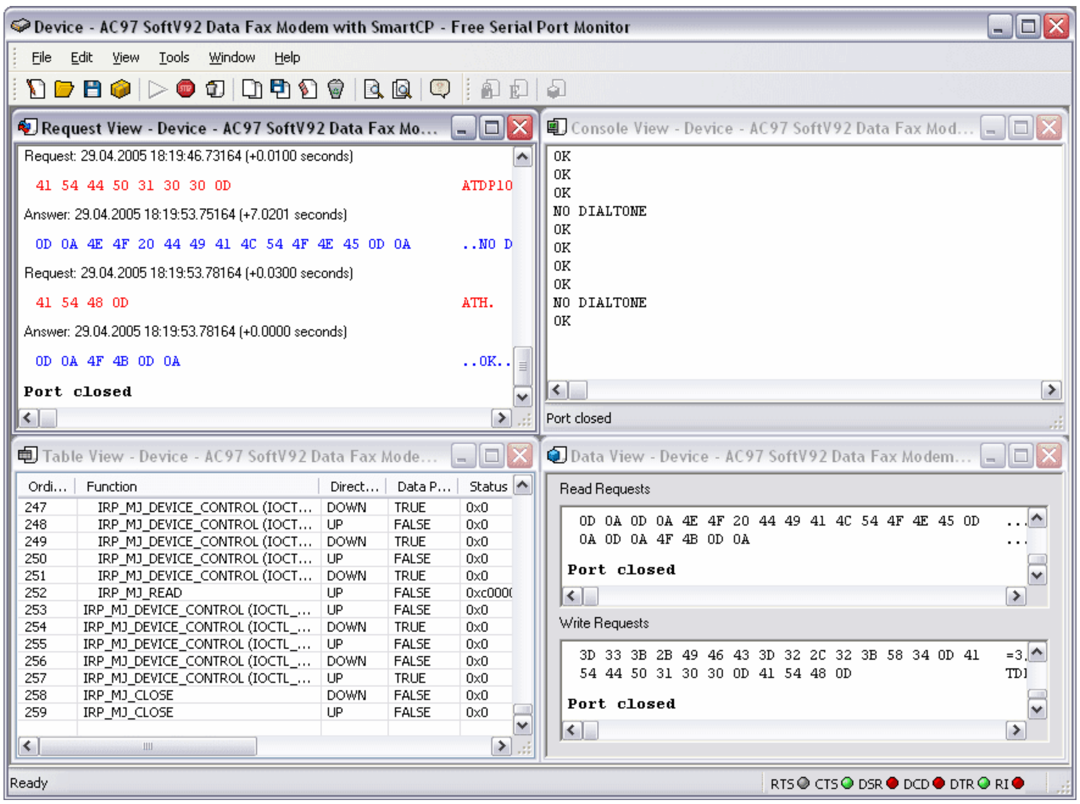


Figure 4.8: ADAM 6050/6017 Trainer

4.2.1.3 MIFARE Card Reader

In order to use the card or a pass card, the serial number of the card is obtained. It is programmed it into the system and every time a person try to access for entering the specific place, the system will identify the person automatically. The cards that are supported by this system are MIFARE, HITAG, Malaysian identification card with touch n go and credit cards with the touch and go. The interface used is RS232 and it is also use the Free Serial Port Monitor program to sniff transaction data from the reader. The Free Serial Port Monitor is shown in Figure 4.9 below.



Ordi...	Function	Direct...	Data P...	Status
247	IRP_MJ_DEVICE_CONTROL (IOCT...	DOWN	TRUE	0x0
248	IRP_MJ_DEVICE_CONTROL (IOCT...	UP	FALSE	0x0
249	IRP_MJ_DEVICE_CONTROL (IOCT...	DOWN	TRUE	0x0
250	IRP_MJ_DEVICE_CONTROL (IOCT...	UP	FALSE	0x0
251	IRP_MJ_DEVICE_CONTROL (IOCT...	DOWN	TRUE	0x0
252	IRP_MJ_READ	UP	FALSE	0xc000(
253	IRP_MJ_DEVICE_CONTROL (IOCTL_...	UP	FALSE	0x0
254	IRP_MJ_DEVICE_CONTROL (IOCTL_...	DOWN	TRUE	0x0
255	IRP_MJ_DEVICE_CONTROL (IOCTL_...	UP	FALSE	0x0
256	IRP_MJ_DEVICE_CONTROL (IOCTL_...	DOWN	FALSE	0x0
257	IRP_MJ_DEVICE_CONTROL (IOCTL_...	UP	TRUE	0x0
258	IRP_MJ_CLOSE	DOWN	FALSE	0x0
259	IRP_MJ_CLOSE	UP	FALSE	0x0

Figure 4.9: Free Serial Port Monitor

4.2.1.4 SMS and GSM Modem

The GSM modem used is the Wavecom Fastrack Modem M1306B and it uses AT command. The desired features that required nowadays are sending SMS, get and reload credit balance and also read the received SMS. There are a few features that applied to the system which is control and sending devices status via SMS and as an alarm reminder. It is also one of the Master Controller add-on modules.

4.2.1.5 Fingerprint Biometric Verification

The fingerprint biometric module in Figure 10 is from Fingertec. It is a complete module with complete features of door access control and complete time management software. It is a good sample of product where the software is covers almost all feature needed with low price. However the module cannot be integrated with the system because the raw data is encrypted and proprietary to third party. The second fingerprint biometric module used is SFM 3550-TCI OEM Programmable shown in Figure 4.11. It's a basic module and can be used and integrated to user application. The module comes with complete manual and software development kit, thus make it suitable for the system.

Figure 4.10: Fingertec fingerprint access system

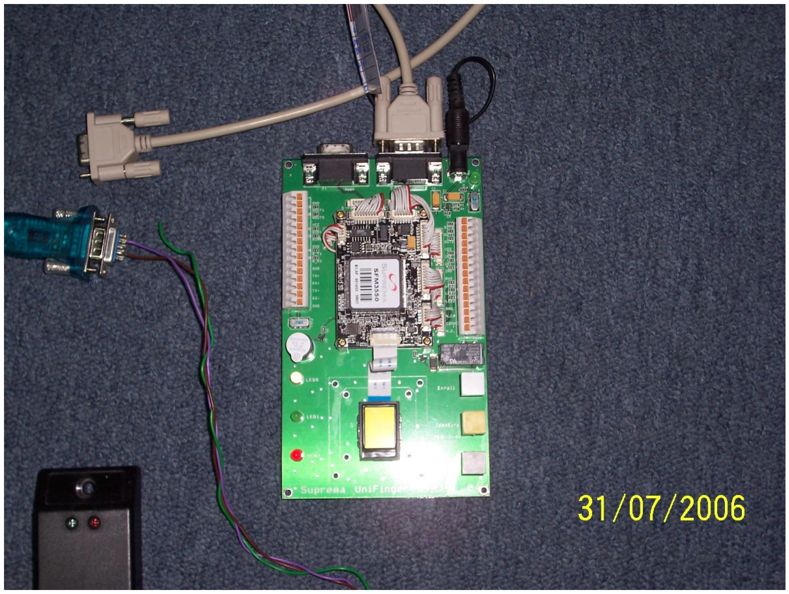


Figure 4.11: SFM 3550-TCI OEM Programmable

4.2.1.6 PC-based Surveillance System

The stage is to develop video monitoring and recording software that can be integrated with the system. This surveillance system used Picollo Pro 3 frame grabber card which has these criteria: -

i. Using VB 6, .Net it is not supported yet.
ii. 8 channel camera recording, uncompressed AVI (very big video file)
iii. Looking for the video compression implementation

The interface and panel for the surveillance system developed are shown in Figure 4.12 and 4.13 below. It also support PTZ camera with RS 485 control interface of the PTZ mechanism. The PTZ control panel is shown in Figure 4.14 below.

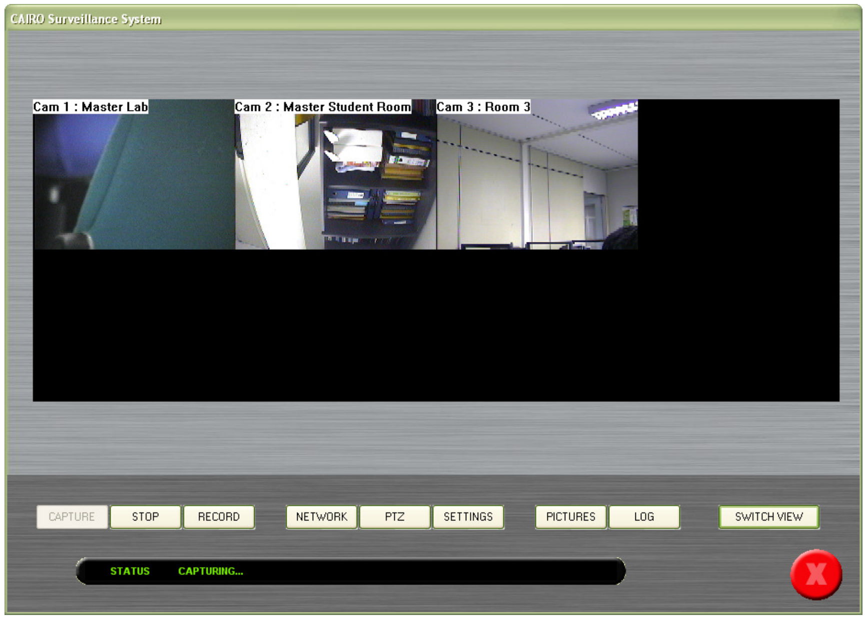


Figure 4.12: Main Page for Surveillance System

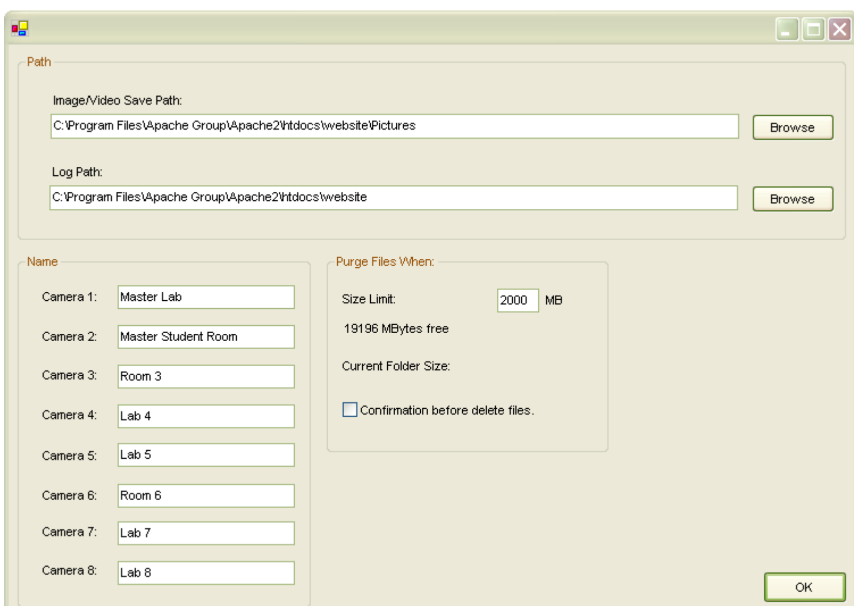


Figure 4.13: Setup Menu for Surveillance System

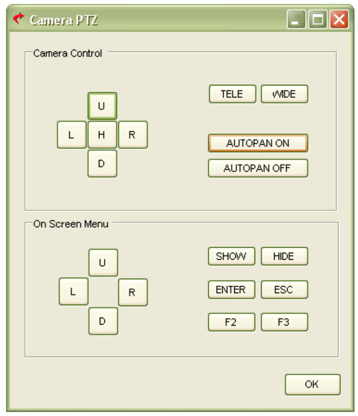


Figure 4.14: PTZ Control

4.2.1.7 IP-Based Surveillance System

IP based surveillance system is consist of AXIS 232D. It can deliver superior quality Motion JPEG and MPEG-4 video in all light conditions over IP networks. It is also can support video motion detection feature built into some Axis cameras, which it can save the network bandwidth as images. The images are only will sent when a motion is detected. There is no recording limitation in the software. We can do remote access via a Web browser or Windows client by enabling control of PTZ and the dome cameras. The alarm alert functions in two ways which it will beep and an e-mail will be sent. Full duplex, real-time audio also support without recording.

4.2.1.8 Ethernet-Based Embedded System

There are lots of embedded systems that are available in the market. For this project, a few of these embedded controllers are tested to evaluate their performance in order to select one that is suitable to be a controller to host the main system. There are

Rabbit embedded system, DS80C400 TINI Ethernet-based embedded system, ADAM6500 controller and Embedded Linux.

a) Rabbit Embedded System

Specifications for Rabbit Embedded system are:

- Powercore module with TCP/IP
- Clock speed up to 51.6 MHz
- Onboard Power Supply (10-60 VAC, 8-43 VDC)
- On-board analog (AC Crossover, ramp generator, temperature sensor)
- 512K Flash
- Max. 1MB SRAM (512K code / 512K data)
- Max. 1MB Serial Flash
- 39 general-purpose I/O
- 10/100 Compatible Ethernet

Even though it is one of a famous embedded system but it still have some problems and disadvantages that has to overcome. The problems with this rabbit embedded system uses complex development programming tool. It is also a proprietary C extension (Dynamic C) and limited flash memory which a lot of function could not be implemented.

b) TINI Ethernet Based System

DS80C400 TINI Ethernet-based Embedded System is a Java based embedded controller which is using the TINIOS. The operating frequency for this embedded system is 40MHz. It also has the same problem with rabbit embedded system which is, it has limited flash memory that a lot of function could not be implemented.

c) Advantech ADAM 6500

Another embedded system that is used for system is ADAM 6500. The Specifications for ADAM 6500 are:

- Web-enabled Communication Controller with Intel® StrongARM main features
- Powerful Ethernet-enabled communication controller in a small package
- Built-in Windows CE .NET to run embedded Ethernet applications
- Built-in web server
- Microsoft embedded VC++ development environment supported
- Built-in CompactFlash® slot
- Flash disk for WinCE and user's AP (ADAM-6500: 16 MB, ADAM-6501: 32 MB)
- Built-in real-time clock and watchdog timer
- Offers RS-232 and RS-485 series communication port (ADAM-6500: 3 x RS-232, 2 x rs-485; ADAM-6501: 1)
- Automatic data flow control in RS-485 mode
- Communication speed up to 115.2 kbps
- Easy to mount on a DIN-rail or panel

ADAM 6500 also has advantages and disadvantages that we can see from the system. The advantages of the ADAM 6500 are low power consumption, easy development with Visual Studio .Net 2003/2005 and also easy to port application from desktop to windows CE.Net, TCP/IP, RS232 and RS485 built-in support. There are quite a lot of disadvantages of ADAM 6500 which are:

- Memory leak problem.
- All installed software data lost when power failure.
- Task termination annoyance, or else performance will drop off drastically as the OS tries to multitask.
- Small number of application, development library and support.
- Not all web programming supported, only ASP supported.
- Only Ms SQL 200 database Server supported, unstable and hard to develop.
- Supported features depend on version of Operating System.
- Original version of openWrt embedded Linux release.
- Low cost and easy to get in the market.
- Broadcom 4710@ 200MHz CPU.
- 4MB Flash.
- 16MB RAM.

The problems with ADAM 6500 are, it has no RTC and USB which means that it is limited on hardware expansion.

d) Embedded Linux

Embedded Linux is also another type of embedded system. It has two versions which are Broadcom 4710 and Broadcom 4704. It also has specifications on Broadcom 4710 which are:

- Broadcom 4710@ 125MHz CPU
- 4MB Flash

- 8MB RAM
- Wireless 802.11b/g NIC (mini-PCI)
- 5 port Ethernet switch (4 LAN,1WAN)
- 1 X USB 1.1 Port
- Customized Linux firmware & software
- Problem: No RTC, Currently obsolete

Differ compared to the other version, which is Broadcom 4704, it has its own specifications which are:

- Premium edition ,compatible with previous version
- Broadcom 4704@ 266MHz CPU
- 16MB Flash
- 32MB RAM
- Broadcom Wireless NIC (mini-PCI)
- 5 port ethernet switch (4 LAN,1WAN)
- BCM5325 Switch
- 2 X USB 2.0 Port

Firmware that being used is the latest OpenWrt RC5 White Russian with SquashFS file system. It uses USB devices and there is no hardware modification. Embedded Linux was tested to several devices and also to hardware and software. The peripheral tested with the controller is shown in Figure 4.15 and 4.16 below.

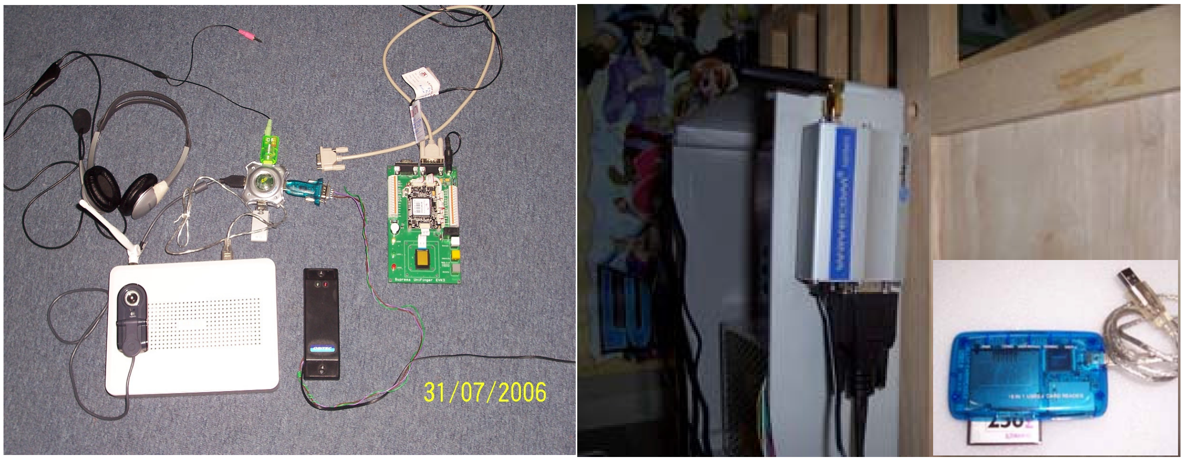


Figure 4.15: Tested with several devices

The tests are done for those software and hardware: -

- USB Storage (usb drive, card reader, usb hdd)
- USB Camera server (motion + pwc driver)
- MP3 player (madplay + MPD+MPC)
- get/set mutliple ADAM6050/17 i/o status
- Secure webserver + php5 support (lighttpd)
- Bluetooth (bluez)
- Sql database (sqlite)
- USB-RS 232 (Ser2net + PL2303)
- Mifare Card Reader Controller (RS 232)
- GSM Modem (RS 232)
- Fingerprint controller communication (RS 232)
- External memory (swap space)

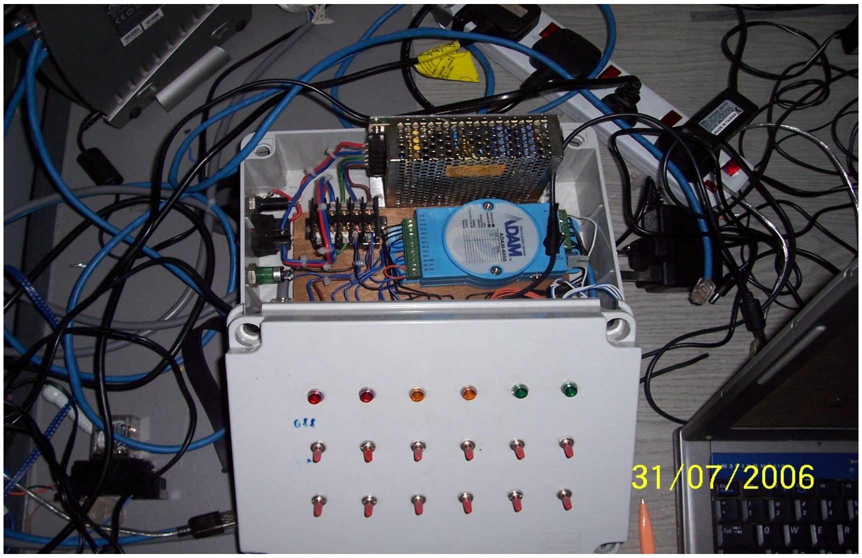


Figure 4.16: Tested with ADAM 6070 I/O module

There are a few advantages and disadvantages when using this Embedded Linux System. One of the advantages is, it is a wide range of hardware support (mipsel, ARM, x86), low cost, readily available in consumer market. It also has a lot of development tools and support, has a lot of built-in network function which are (dhcp server, router, bridge, ADSL (pppoe), proxy, firewall, web server, fileserver, ssh, telnet, console). Besides that, it uses low CPU resource which is most of the time only 1% resource is used. Embedded Linux also has USB host support which is easy for function extends and hardware supported (Bluetooth, webcam, sound card, USB drive, etc).

Embedded Linux does not have a lot of disadvantages. The disadvantage of this system is there is no internal RTC and the system has to synchronize time with other peripheral after power failure. Otherwise, it is being decided to be used as an Embedded Master controller.

4.3 Second Phase : Implementation

The implementation of the system is done after the first phase, which is prototyping stage completed. The Embedded System is being programmed in GNU C language with multi-child process. There is also no object oriented in C, it is a multi-agent concept that has been implemented and one most important thing, it is easier to program. It uses shared memory for agent communication and it is easier and low resource usage. Figure 4.17 to 4.20 shows the figures for all devices that have been setup. This stage involves devices setup, which are:

- 3 doors complete component (card reader, lock, flux sensor)
- 10 motion sensors
- 10 smoke detectors
- 5 ADAM 6050 as I/0 (send status every 100ms)
- 2 ADAM 6017
- 1 GSM Modem

There is also a software customization which is most of it ported from the trunk version which are:

- USB Storage (ext2,ext3,fat)
- USB - Serial Converter (Prolific PL2303)
- USB Audio Sound Card
- USB Webcam (Philip PWC)
- USB Bluetooth (Bluez)
- Secure Web Server + PHP 5 Web Programming
- SQLite Database
- Swap file support (for virtual memory support)
- Remote Sound Player & Client

Figure 4.17: Broadcom 4704 Main Controller with I/O modules

Figure 4.18: Mifare Card Reader for door access control

Figure 4.19: Dome Passive Infrared Sensor (PIR) and smoke detector

Figure 4.20: Magnetic Door Sensor and Magnetic Lock

4.4 Embedded Programming Manual

4.4.1 Introduction

The embedded system is developed on Openwrt Linux Platform. This system is written in C language and compiled using Open Source GNU Compatible Compiler (GCC). For router version, GCC compiler for Mipsel version is required. This compiler can be downloaded from OpenWRT website. Sqlite database is used as database since it lightweight, small size and using a flat file. It's easy to be implemented on embedded Linux system.

The embedded system is developed in modules and using several child processes since the automation part requires real time processing. Using the child processes, the processing function could be executed simultaneously without interrupting other processes.

Since the system running on several child processes, every child process will copy the entire variable declared and the variable is different between every child process. So that, a shared memory variable is required to enable all the child processes could share the variable and communicate with each other. The system uses SHM shared memory since it is easy to be implemented and support arrays as its variable.

The modules developed are as follows:

- I / O modules
  - ADAM 6050 module
  - CAIRO RS232 I/O module
- Automation modules
  - Door
  - Security System
  - Fire Alarm System

- Database modules
    - Sqlite database
- Server modules
    - TCP/IP server module
- SMS modules
    - Wavecomm GSM Modem module
- Mifare card reader module
    - M-Smart mifare card reader
- Fingerprint module
    - Suprema fingerprint reader

4.4.2 System Architecture

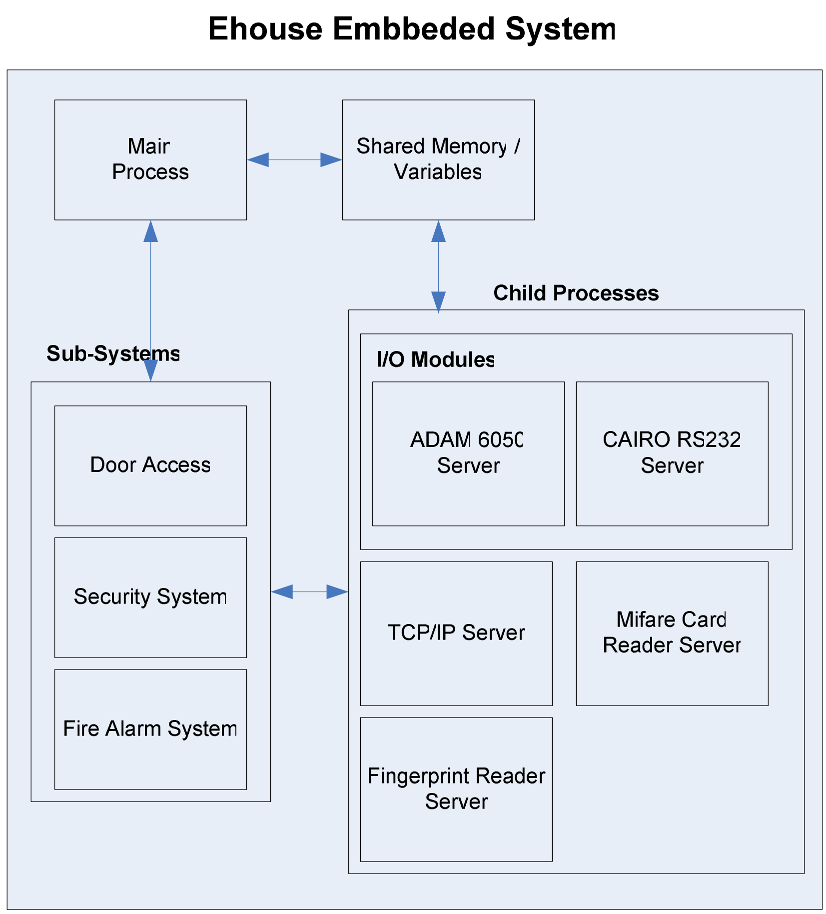


Figure 4.21: System Architecture

4.4.2.1 Tools

There several tools used to develop the embedded system. They are as follows:

- Kate (File Editor)
- Ethereal (Network Sniffer)
- HHD Free Serial Port Monitor (Serial Port Sniffer)
- Sqlite Administrator (Sqlite database administration)

4.4.3 Programming Guide Work Flow

4.4.3.1 Main program

The main program routine is in **ehouse.c** file in Main() function. All the shared variables are defined and all the child processes are triggered here. The work flow is shown in Figure 4.22 below.

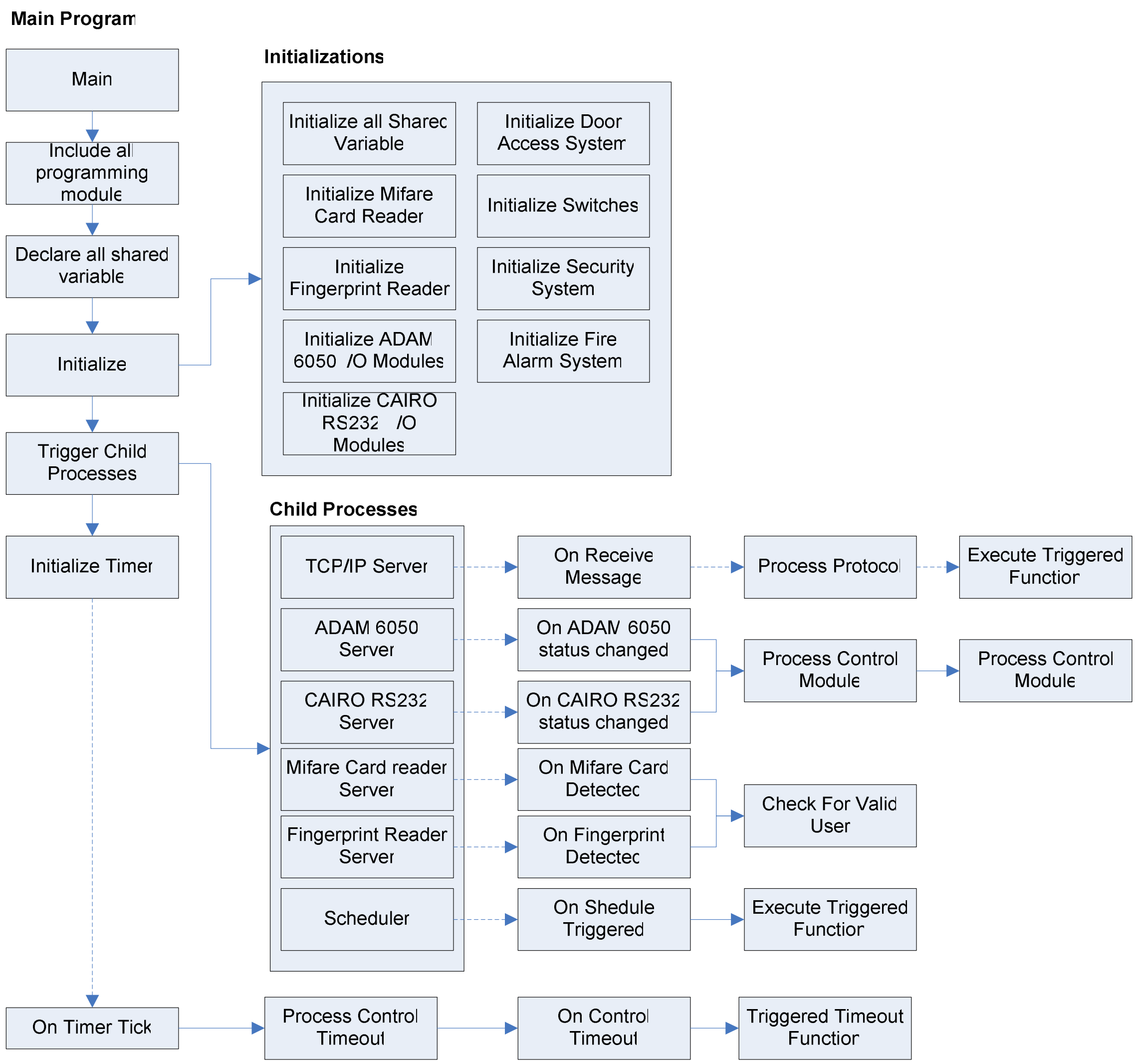


Figure 4.22: Main Program Workflow

4.4.4 I/O Modules

4.4.4.1 ADAM6050

ADAM 6050 support streaming method using Universal Diagram Protocol (UDP) and MODBUS protocol to several target devices on port 512. ADAM 6050 module will send a status message every 100 milliseconds to the target network device. Since that, it just needs to write a listening server on Port 512 to catch the entire status message sent over the network. The ADAM module work flow is shown in Figure 4.23 below.

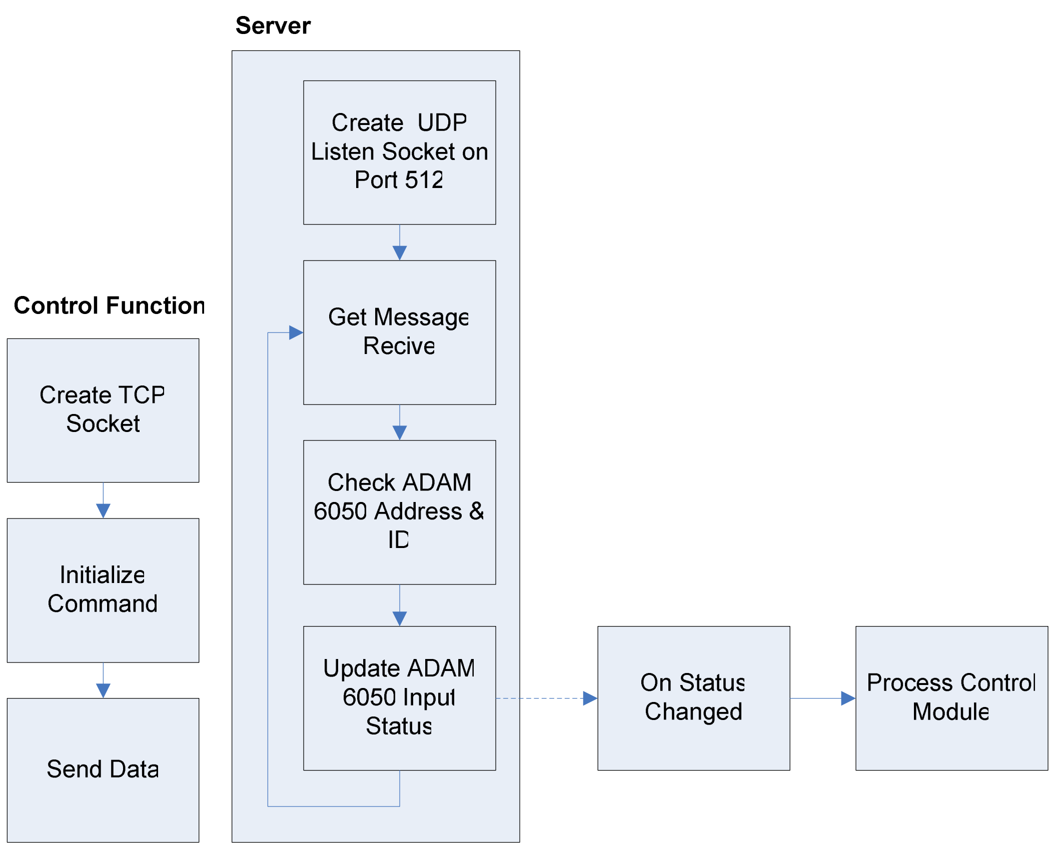


Figure 4.23: ADAM 6050 Module Work Flow

4.4.4.2 CAIRO RS232

CAIRO RS232 I/O Modules communicate over RS232. So a module written to handles RS232 messaging. It's a passive controller, so a status message must be request continuously to get the latest I/O status. The RS232 module work flow is shown in Figure 4.24 below.

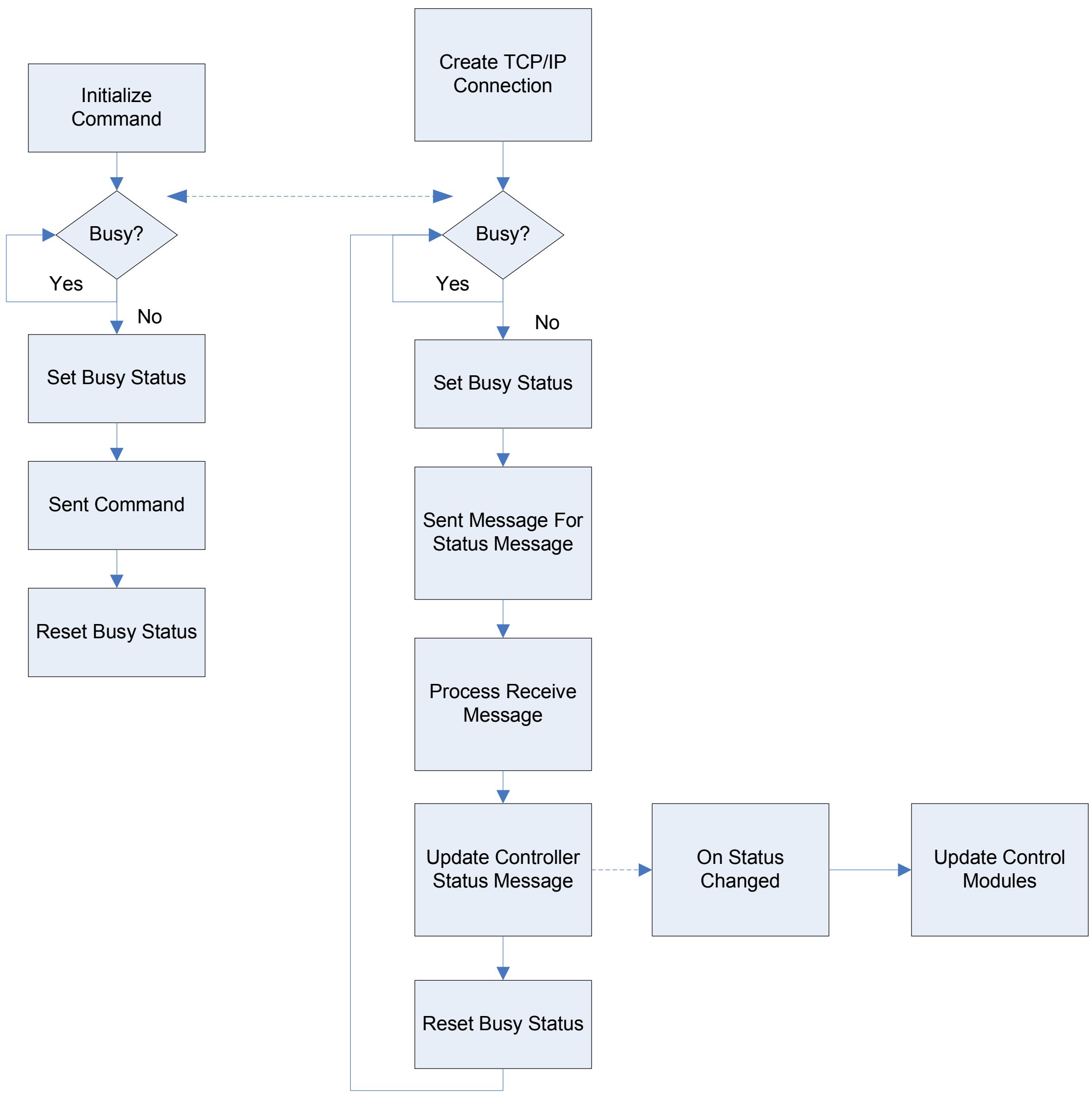


Figure 4.24: CAIRO RS232 I/O Modules Work Flow

4.4.4.3 MIFARE Card Reader

M-Smart Mifare Card Reader is easy to handle since it only require an RS232 connection opened. A message will be sent trough RS232 when a mifare card is detected. But since Ser2net is used, a message must be sent to make sure the connection alive. The Mifare card reader module work flow is shown in Figure 4.25 below

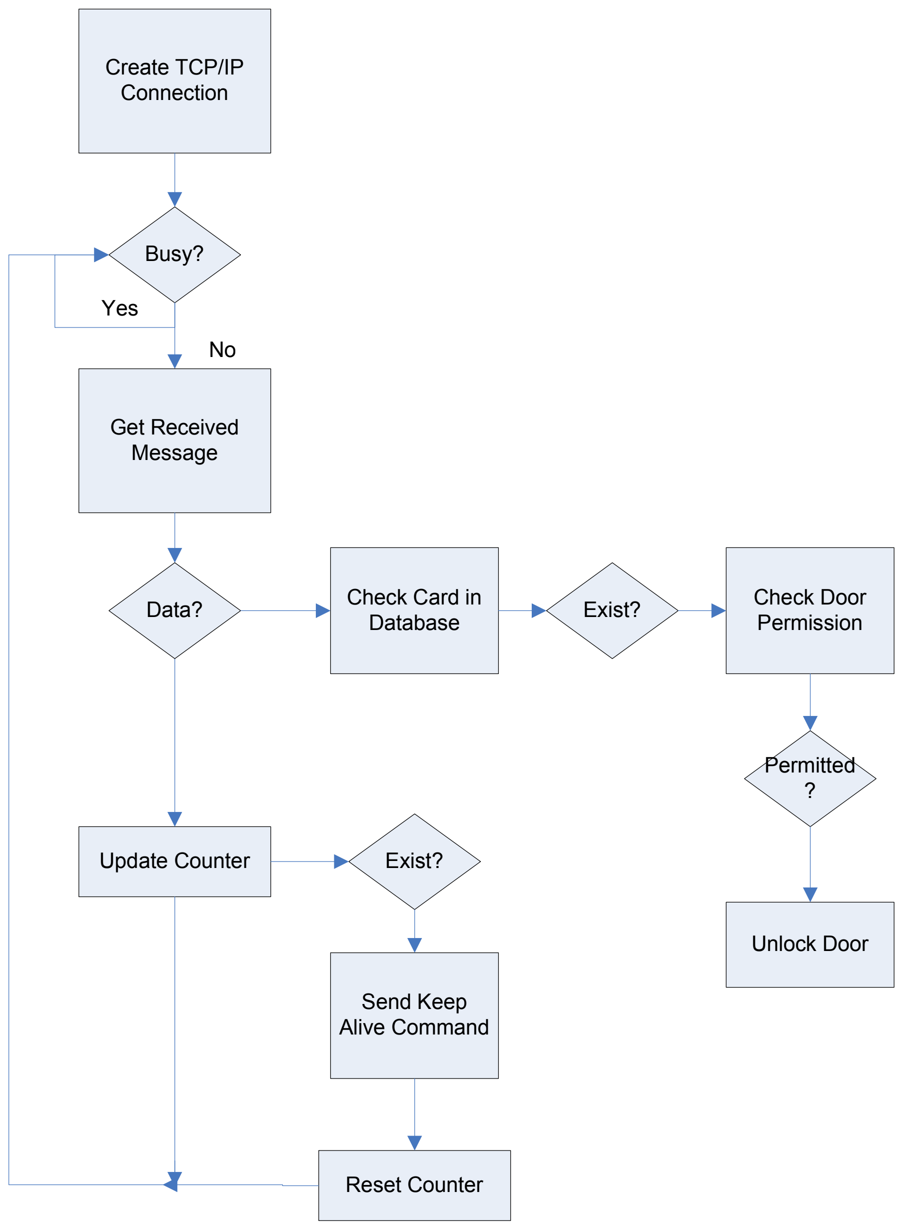


Figure 4.25: MIFARE Card Reader

4.4.4.4 Fingerprint Reader

Suprema Fingerprint controller is also easy to handle since it only require an RS232 connection opened. A message contain user id will be sent when a fingerprint detected. But since Ser2net is used, a message must be sent to make sure the connection alive.

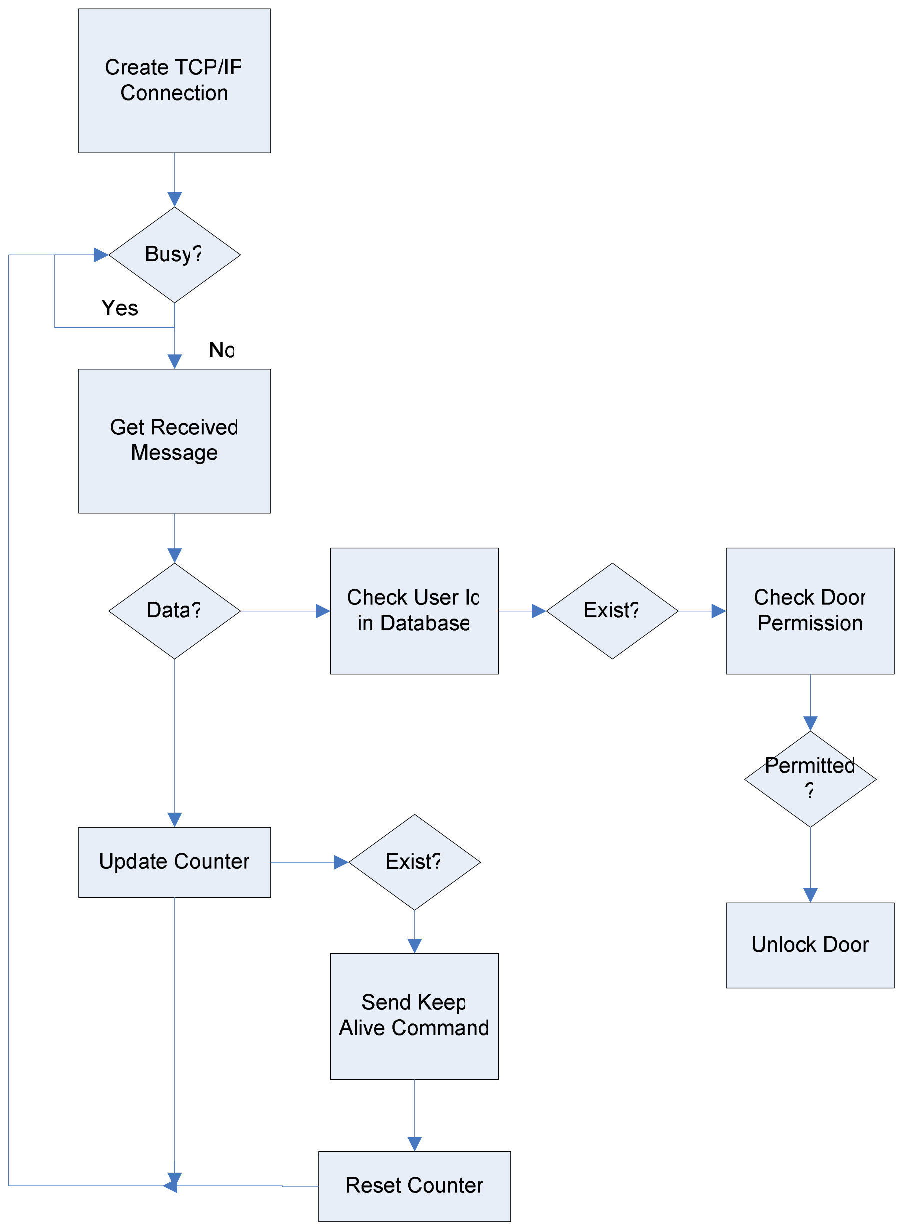


Figure 4.26: Fingerprint reader work flow

4.4.5 Control Modules

4.4.5.1 Door Access

Door access module is working together with mifare card reader module and fingerprint module. When a card detected or fingerprint detected, the card or fingerprint id will be compared in database. If the card or fingerprint id is valid, door access function will be triggered.

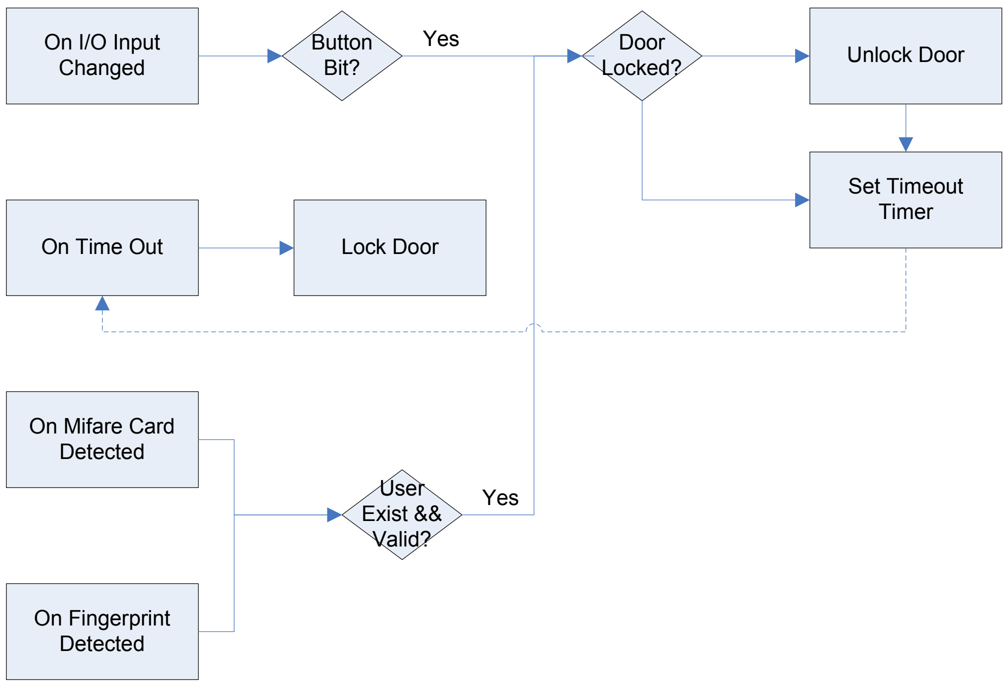


Figure 4.27: Door access work flow

4.4.5.2 Switch

Switch module working in 3 modes, Energy Saving, Always On and Always Off. In Energy Saving mode, the switch will be turned on and turned off automatically regarding the timeout defined.

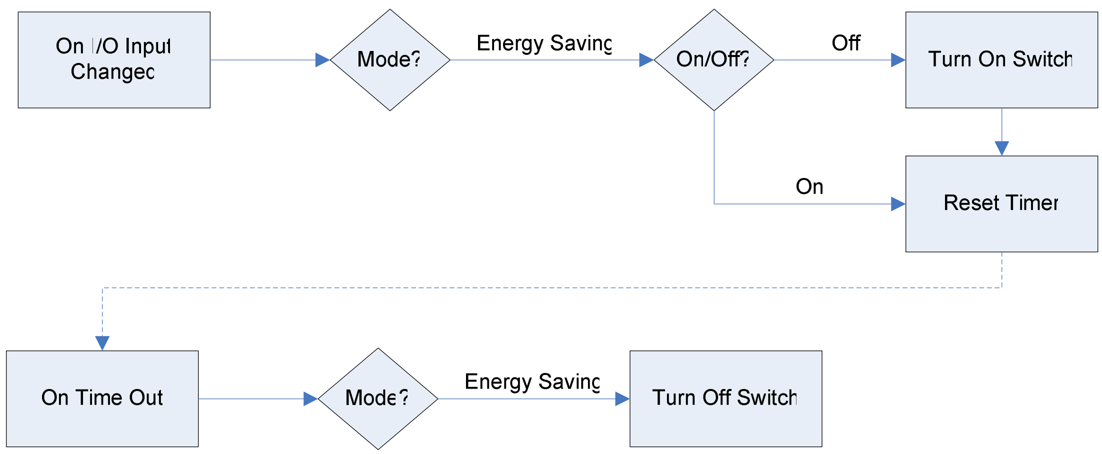


Figure 4.28: Door Access Work Flow

4.4.5.3 Security System

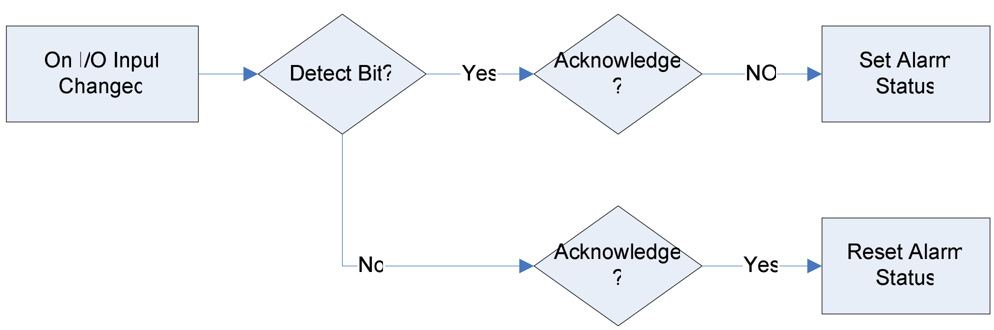


Figure 4.29: Security System Work Flow

4.4.5.4 Fire Alarm System

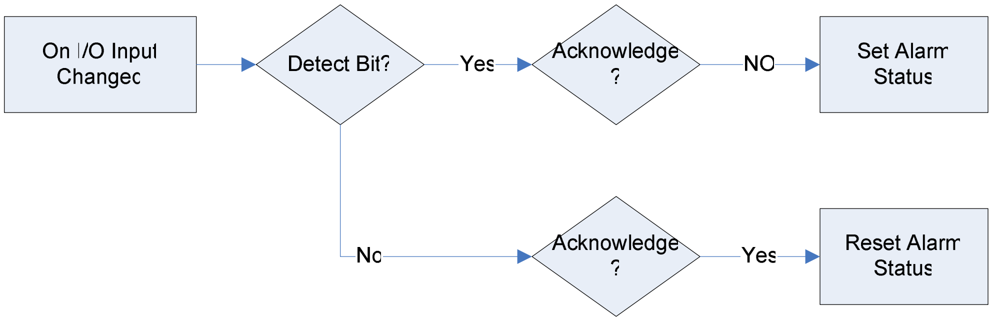


Figure 4.30: Fire Alarm Work Flow

4.4.5.5 Scheduler

The scheduler could be defined in 2 ways, by date or by day. By day, the scheduler will be triggered if day and time is exists in the database. By date, the scheduler will be triggered id date and time is exists in the database. If the scheduler is triggered, a message will be defined and processed to execute the defined action.

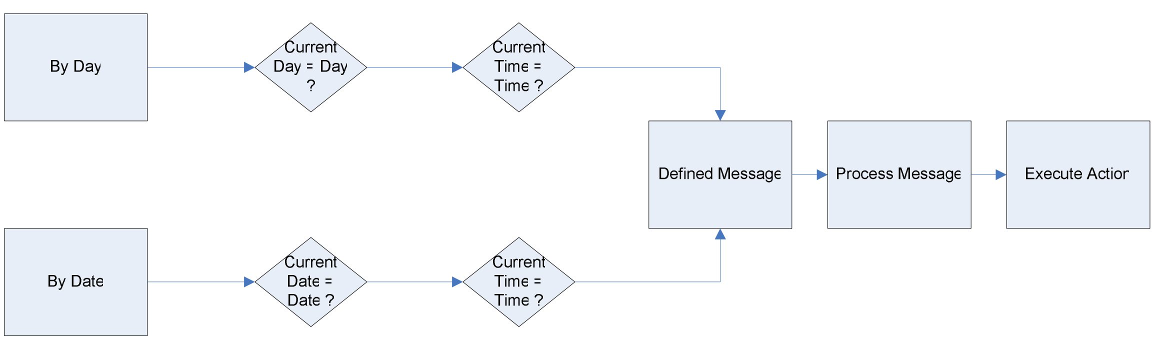


Figure 4.31: Scheduler Work Flow

4.4.5.6 Short Message Service (SMS)

SMS module contains 3 main routines, SMS Control, SMS Gateway and SMS Timer. SMS Control is for automation control through SMS. SMS gateway enable user to send SMS from their computer over the network. SMS Timer will send all the SMS received from SMS Gateway to the corresponding mobile phone users.

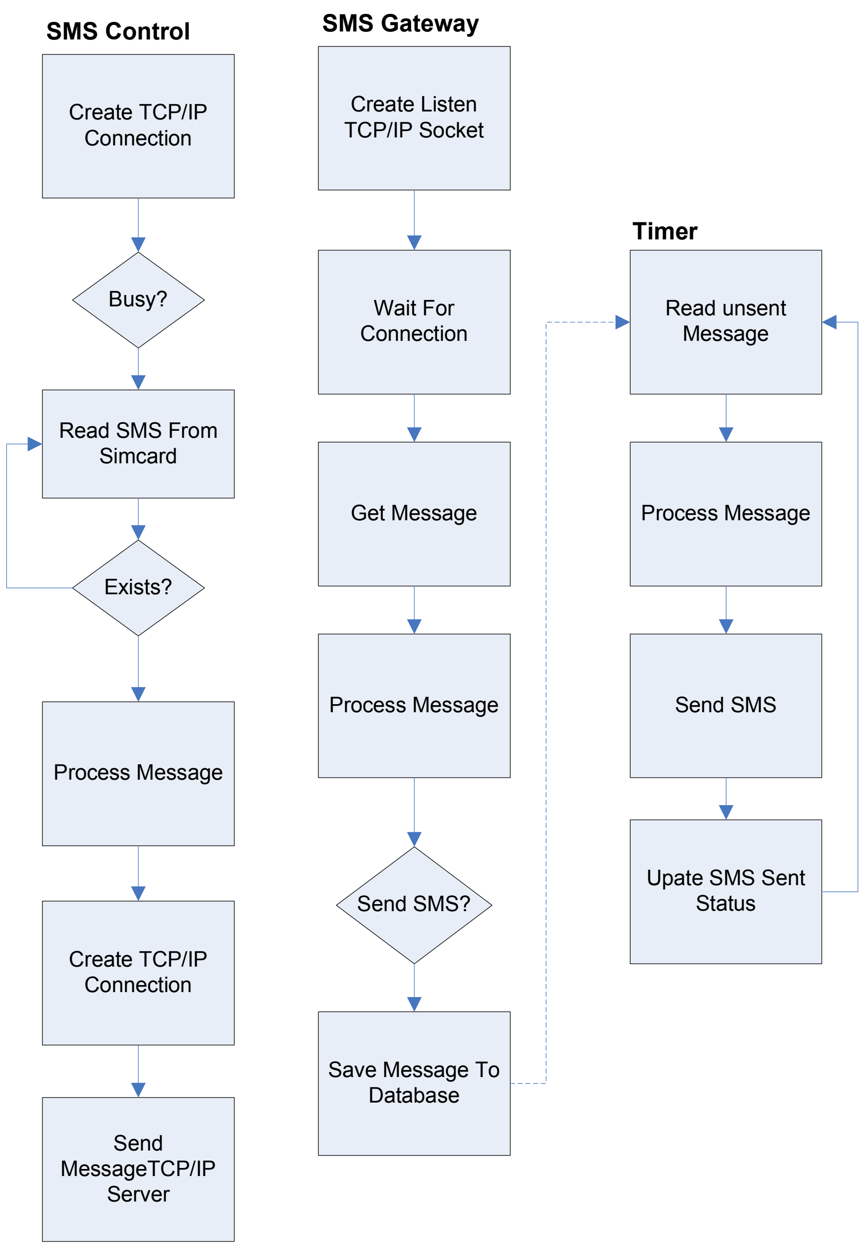


Figure 4.32: SMS Work Flow

4.4.5.7 Server

To create a TCP/IP server, a TCP/IP must be created and bind to the listen socket. Then, the server will wait for connection. If the connections exist, a client socket will be accepted and the message from the client can be read.

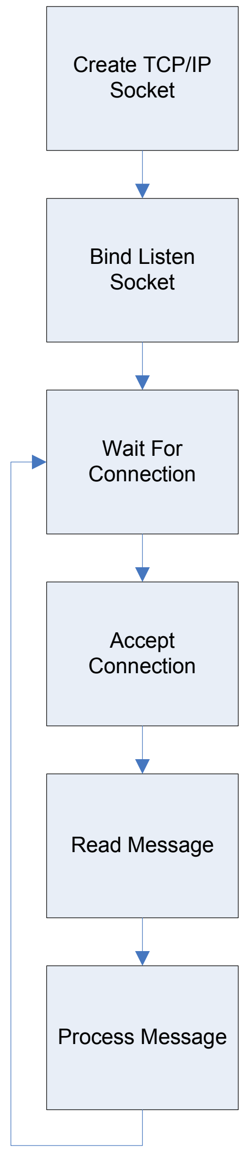


Figure 4.33: Server Work Flow

4.5 Intelligent Approach and Solutions

In order make the system smarter and friendly, a monitoring level system need to be created. This system will supervise the house like a human. For example, when there is nobody around the house appliances need to be switched off or perhaps when atmosphere is hot, the system will be able to switch the fan to higher speed. Hence, in order to produce such system, an artificial intelligence methodology such as fuzzy logic and expert system needs to be applied.

Of course there are sensors and rules which make the system intelligent. The sensors will be used as the eye and ear of the system while the rules implanted in the program will act as the brain of the system. For the controlling system such as adjusting the light, fuzzy controller will be used. The usage of fuzzy controller in this matter is due to its fast response in achieving steady state. Then at the monitoring level, a level higher than the fuzzy controller expert system rule base is applied.

The next level is to develop a system that has the ability to adapt to the lifestyle of an inhabitant. This system able to learn the habits of the inhabitant to on/off the lights and fan base on the previous data collected. The artificial neural network technique is used to develop the algorithm. A database management system is used to store the data and provide useful information to Neural Network algorithm.

There are 3 main system for the neural network based development which include learn to on/off the devices base on the time recorded in the database when the inhabitant on/off the devices, learn the level of brightness and also level of fan desired base on the outside temperature and outside brightness that influence the react of inhabitants previously.

4.5.1 Fuzzy Logic and Expert System

The database is required to accumulate the data from the sensors implanted in the house. This means that to build up the tables for storing the data and also declaration on type of data also need to be specified in order to let the software know the type of data that will be stored. Then a reference of this database is added in the source code for the database to create the link. This database is important for fuzzy logic and expert system algorithm development.

4.5.1.1 Building the Algorithm for Fuzzy Controller

Fuzzy logic has many advantages such as it can represent vague language naturally. This is due to its fuzziness characteristic. Besides that fuzzy logic enrich the data and do not replace the data. Besides that, fuzzy logic is also simple to design, often works and can improve performance model. Hence by using fuzzy logic to build fuzzy controller will bring many benefits. Besides that fuzzy controller is able to design along linguistic lines which is the usage of rules based on experience. Figure 4.34 shows the typical fuzzy controller.

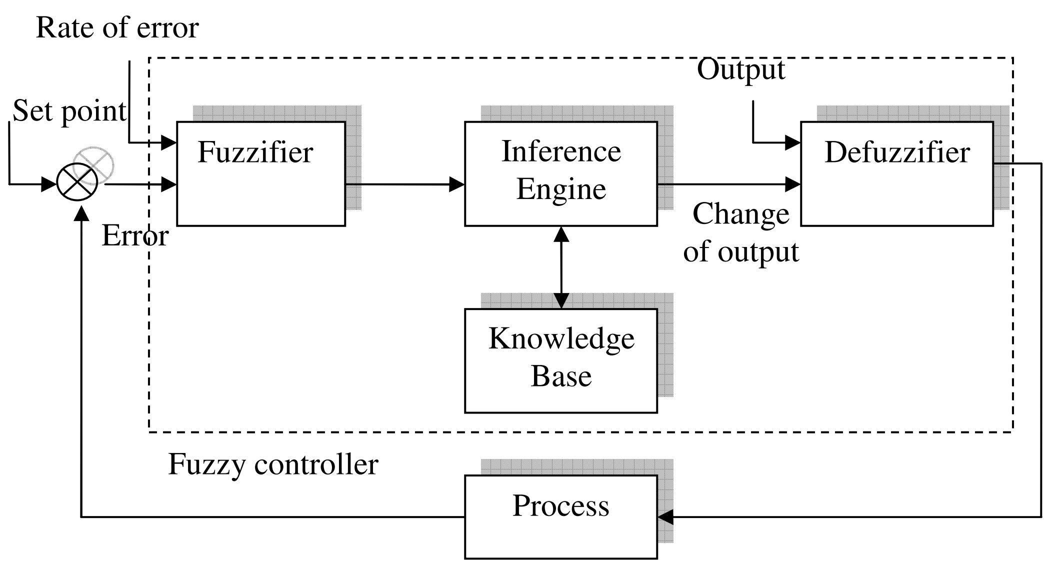


Figure 4.34: Typical fuzzy controller with process

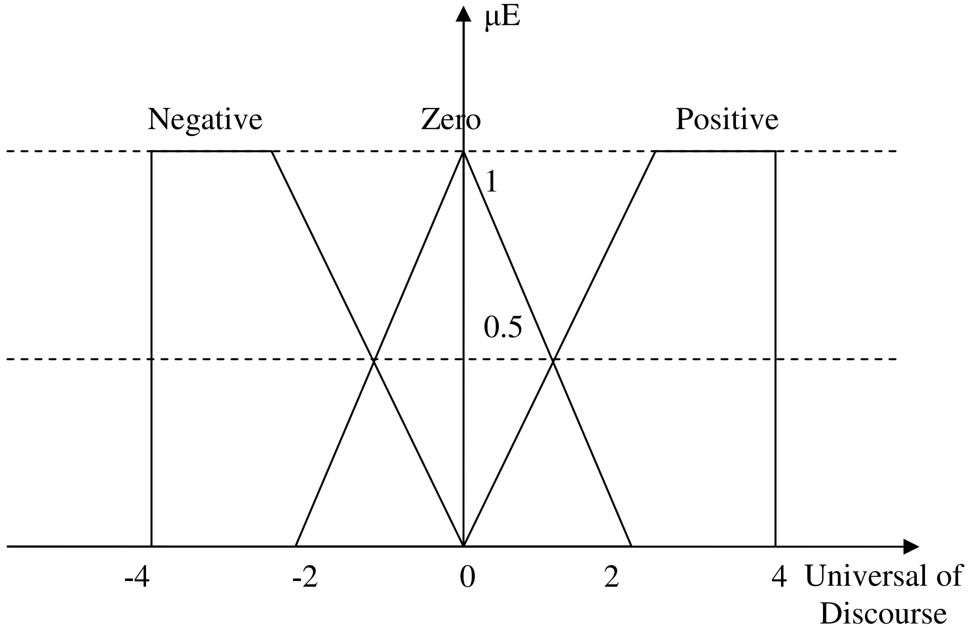
4.5.1.2 Fuzzification

Fuzzification is a process which involves the conversion of the input or output signals into a number of fuzzy represented values (fuzzy sets). In this project, the inputs to the fuzzifier are error and change of error. As for the membership functions a combination of a triangular function and trapezoid functions are used. Triangular function and trapezoid function are used due to the characteristics of easy computing. Then the labels for the respective membership functions are such as negative, positive and zero.

For the values of the universal of discourse for error it will be the boundary of light (LED) voltage operating range which is between -4 volt and 4 volt. For change of error it would be between -2 volt and 2 volt. Figure 4.35 and Figure 4.36 shows the equations involved and the membership functions. The data that fed into the membership function will be fuzzified according to the boundary stated in the functions. Hence fuzzy data will be produced from the crisp data.

4.5.1.3 Knowledge Base

The knowledge base of a fuzzy logic controller consists of a data base and rule base. The basic function of the data base is to provide the necessary information for the proper functioning of the fuzzification module, the rule base and the defuzzification module. The basic function of the rule base is to represent the expert knowledge in a form of “if-then” rule structure. In order to derive the rule base, four approaches can be used which are expert experience and control engineering knowledge, rules based on operator’s control actions, rules based on fuzzy model of a process and rules based on learning.



Equations Involved:

Error (E) = Set Point(r) – Output (y)

For the membership functions:

If $-4 \leq Error \leq -2$

Negative = 1

If $-2 \leq Error \leq 0$

Negative = (-Error) / 2

Zero = (2+Error) / 2

If $0 \leq Error \leq 2$

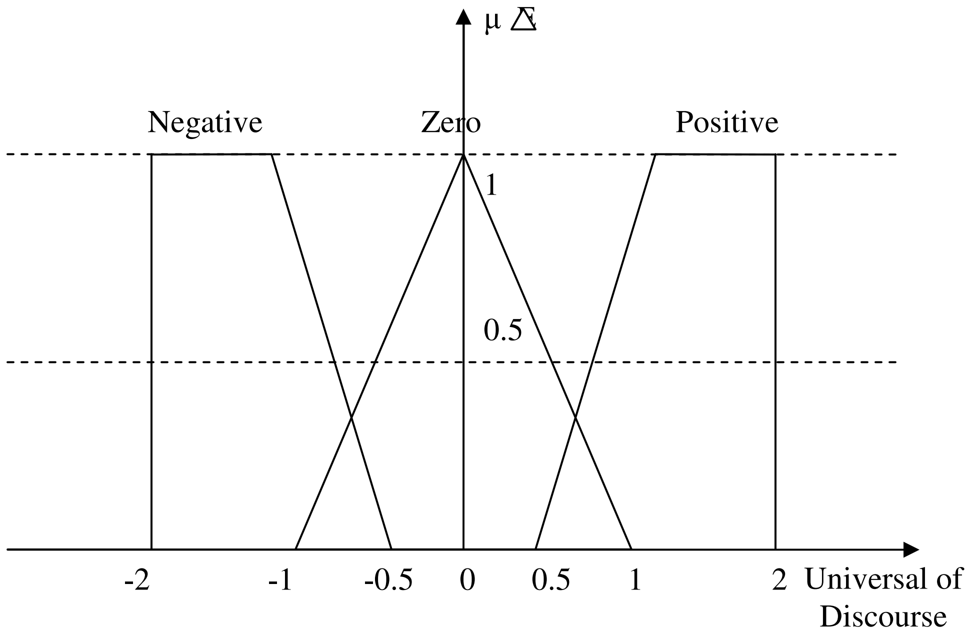
Zero = (2 – Error) / 2

Positive = (Error) / 2

If $2 \leq Error \leq 4$

Positive = 1

Figure 4.35: **The membership functions and the equations involved for Error**



Equations Involved:

Rate of Error (Δ E) = [Error (t) – Error (t-1)] / 2

For the membership functions:

If $-2 \leq \Delta Error \leq -1$

Negative = 1

If $-1 \leq \Delta Error \leq 0$

Zero = 1+ Δ Error

If $-1 \leq \Delta Error \leq -0.5$

Negative = –1 – 2 *(Δ Error)

If $0 \leq \Delta Error \leq 1$

Zero = 1 – Δ Error

If $0.5 \leq \Delta Error \leq 1$

Positive = 2*(Δ Error) – 1

If $1 \leq \Delta Error \leq 2$

Positive = 1

Figure 4.36: **The membership functions and the equations involved for Δ Error**

In this project the method chosen is the approach of expert experience and control engineering knowledge. Actually this method is the least structured of the four methods mentioned just now and yet it is one of the most widely used methods. This method is based on the derivation of rules from the experience based knowledge of the process operator and control engineer. Figure 4.37 below shows the rule base of project in the "if-then" rule structure while Figure 4.38 shows the rule base in matrix form.

If Error = Negative and ΔError = Negative
Then ΔOutput = Positive
If Error = Negative and ΔError = Zero
Then ΔOutput = Small Positive
If Error = Negative and ΔError = Positive
Then ΔOutput = Zero
If Error = Zero and ΔError = Negative
Then ΔOutput = Small Positive
If Error = Zero and ΔError = Zero
Then ΔOutput = Zero
If Error = Zero and ΔError = Positive
Then ΔOutput = Small Negative
If Error = Positive and ΔError = Negative
Then ΔOutput = Zero
If Error = Positive and ΔError = Zero
Then ΔOutput = Small Negative
If Error = Positive and ΔError = Positive
Then ΔOutput = Positive

Figure 4.37: The rule base in "if-then" rule structure

		Error		
		N	Z	P
	N	P	SP	Z
ΔError	Z	SP	Z	SN
	P	Z	SN	N

Legends:
N – Negative
P – Positive
Z – Zero
SP – Small Positive
SN – Small Negative

Figure 4.38: The rule base in matrix form

From Figures 4.37 and 4.38, this rules are derivate through expert experience. About the rate of change of output it will be discussed later. Anyhow for the defuzzification there are five membership functions, hence there are five different outputs in the rule base. Normally three membership functions are chosen, however in this case five membership functions are chosen to have a more precise and controlled output. An example on how this rule base is fired. So whenever Error = Positive and ΔError = Positive then the ΔOutput = Negative. In other words, if the brightness is too bright, then lower the voltage. This goes the same for all the other rules. If Error = Negative and ΔError = Negative then the ΔOutput = Positive. To represent it in a different way, if the brightness is too dark then increase the voltage.

4.5.1.4 Inference Engine

The inference mechanism provides the mechanism for invoking or referring to the rule base such that the appropriate rules are fired. The inference or firing with this fuzzy relation is performed via the operations between the fuzzified crisp input and the fuzzy relation representing the meaning of the overall set of rules. As a result of the composition, one obtains the fuzzy set describing the fuzzy value of the overall control output.

In this project the method used is root sum square methodology. This method is used because it combines the effects of all applicable rules, scales the functions at their respective magnitudes, and computes the fuzzy centroid of the composite area. Although this method is more complicated mathematically than other methods, but was selected for this case since it seemed to give the best weighted influence to all firing rules. This methodology will firstly find the minimum value for the rules that fired and then root sum square is performed for the rules having the same consequent (ΔOutput). Root sum square is performed by squaring the firing angle and sum up the values that fired the same consequent, then root two the value. To further understand on this, refer to Table 4.1 where examples of the values are shown.

Table 4.1: **Examples of data for obtaining the respective ΔOutput values**

Error	ΔError	Error			ΔError			ΔOutput				
		P	Z	N	P	Z	N	P	SP	Z	SN	N
-3	-1.5	0	0	1	0	0	1	$\sqrt{2}$	0	0	0	0
3	1.5	1	0	0	1	0	0	0	0	0	0	$\sqrt{2}$
-1	-0.5	0	0.5	0.5	0	0.5	0	0	0.5	0.5	0	0
1	0.5	0.5	0.5	0	0	0.5	0	0	0	0.5	0.5	0
2	0.7	1	0	0	0.4	0.3	0	0	0	0	0.3	0.4
-0.5	0.7	0	0.75	0.25	0.4	0.3	0	0	0.25	0.39	0.4	0

The values shown in Table 4.1 are obtained based on Figure 4.35, 4.36, 4.37, 4.38 and 4.39. When Error = -0.5 and ΔError = 0.7, there are two zero consequent fired. Hence the calculation performed for obtaining the ΔOutput value is as shown in as shown in Figure 3.8.

ΔOutput = [(minimum (Error (Z), ΔError (Z))) ^ 2 + (minimum (Error (N), ΔError (P))) ^ 2] ^ 0.5

= [(minimum (0.75, 0.3)) ^ 2 + (minimum (0.25, 0.4)) ^ 2] ^ 0.5

= [0.3 ^ 2 + 0.25 ^ 2] ^ 0.5

= [0.09 + 0.0625] ^ 0.5

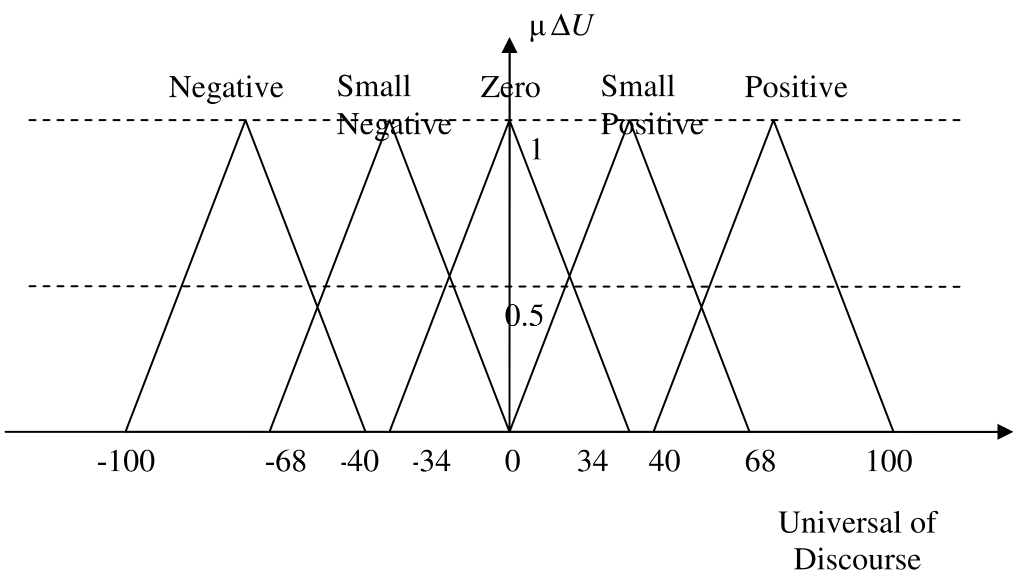
= [0.1525] ^ 0.5

= 0.39

Figure 4.39: **Root sum square calculations**

4.5.1.5 Defuzzification

Defuzzification is a mapping from a space of fuzzy control actions defined over an output universe of discourse into a space of non-fuzzy (crisp) control action. This process is necessary because in many practical applications crisp control action is required to actuate the plant. The defuzzifier also performs an output denormalization if normalization is performed in the fuzzification module. In this project the centre of gravity method is used due to easy programming. Besides that, this procedure is the most prevalent and physically appealing of all the defuzzification method. However in this project the intervals for the membership function is large. In real application, the smaller intervals better and more precise output will be produced. However the smaller it gets the harder to compute the algorithm. Anyway Figure 4.40 shows the membership functions for the defuzzification module.



Δ Output (ΔU) = (Negative * -70 + Small Negative * -34 + Small Positive * 34 + Positive * 70) / (Negative + Small Negative + Small Positive + Positive)

Output (t) = Output (t) + Output (t-1)

Figure 4.40: The Membership Function and Equations for Defuzzification Module

4.5.2 The Monitoring Level Expert System

In this project, expert system is used as the methodology to develop the monitoring level system and for that matter, the reasoning used is forward chaining. This means data will be provided to the system and let the system draws conclusions. The flow chart for the monitoring level system is shown in Figure 4.43. The flow chart shown is the monitoring level system integrated with the sensors which can be found in the model shown in Figure 4.41.

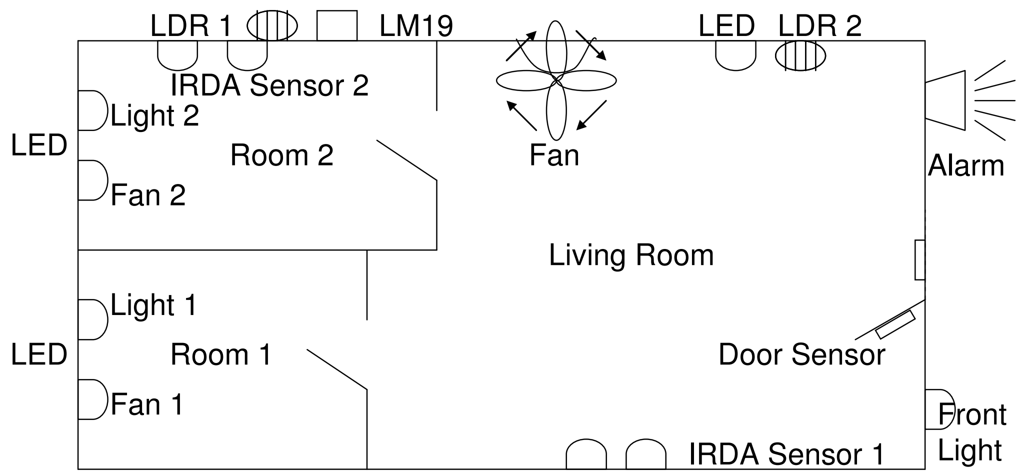


Figure 4.41: The house plan with the respective sensors

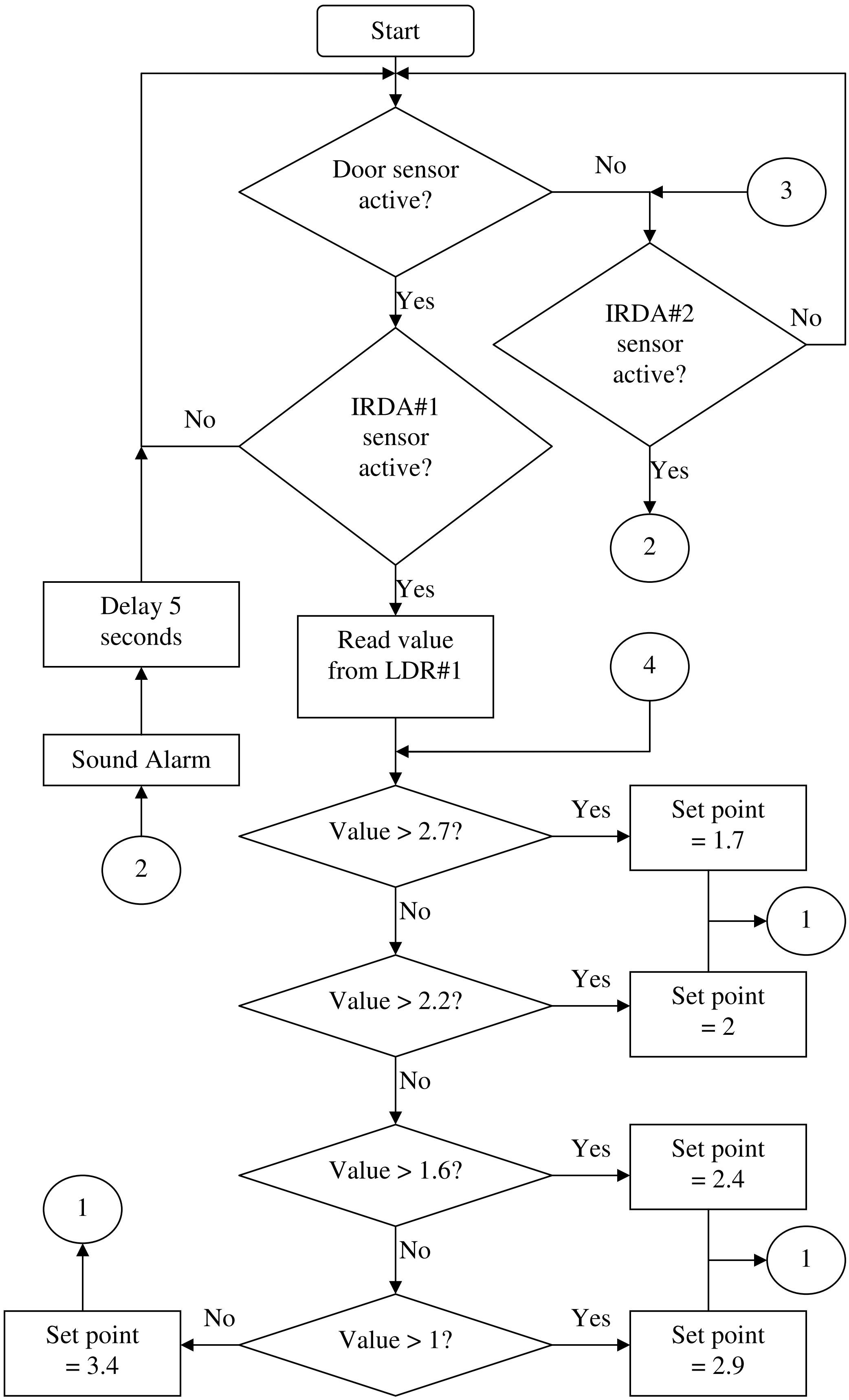
Based on the flow chart shown, the system will always scan for the presence of people through door sensor and IRDA#1 sensor. Hence whenever both of these sensors are activated in the first place then the system will directly obtain a value from LDR#1 sensor which is located outside of the house. This sensor will actually provide the ambient brightness to the system. Then based on the value read or the ambient brightness, the system will set a set point to the fuzzy controller.

Hence based on the set point, the fuzzy controller will adjust the house brightness until the set point is achieved. When the light of the house is adjusted, then the system will adjust the motor accordingly. After adjusting the motor the system will scan for manual overwrite priority. If this function is active, the system will hand over the controlling power to the user where the user gets to input the desirable brightness and fan speed. Then the system again checks for the presence of people by using the IRDA#1 sensor and door sensor. However this time is different because as long as one of the sensors is active then the system will still be active. Hence the system will automatically turn off when both of these sensors are inactive. After going through this scanning, the system will check for the changes in the ambient brightness. If the ambient brightness is the same, then the system will proceed to another loop. However if the ambient brightness changes, the system will obtain a new set point, then the fuzzy controller will adjust the light and fan accordingly.

So this process will go on and on u until the user switches to another form. To understand further on the rule base of the expert system, please refer to Figure 4.42 where the rule of the expert system is shown in the "if-then" structure.

If *there are people in the room*
    Then *switch on the fan and light*
If *there are no people in the room*
    Then *switch off the fan and light*
    If *the outside brightness is very bright*
        Then *it is very hot and very bright*
    If *the outside brightness is bright*
        Then *it is hot and bright*
    If *the outside brightness is dim*
        Then *it is cool and dark*
    If *the outside brightness is very dim*
        Then *it is very cool and very dark*
        If *it is very hot and very bright*
            Then *fan power high and light brightest*
        If *it is hot and bright*
            Then *fan power medium high and light bright*
        If *it is cool and dark*
            Then *fan power medium low and light dim*
        If *it is very cool and very dark*
            Then *fan power low and light dimmest*

Figure 4.42: The rule base in "if-then" structure for the expert system



Start
Door sensor active?
No
3
IRDA#2 sensor active?
No
Yes
2
Yes
IRDA#1 sensor active?
No
Yes
Delay 5 seconds
Read value from LDR#1
4
Sound Alarm
2
Value > 2.7?
Yes
Set point = 1.7
1
No
Value > 2.2?
Yes
Set point = 2
No
Value > 1.6?
Yes
Set point = 2.4
1
No
1
Value > 1?
No
Set point = 3.4
Yes
Set point = 2.9

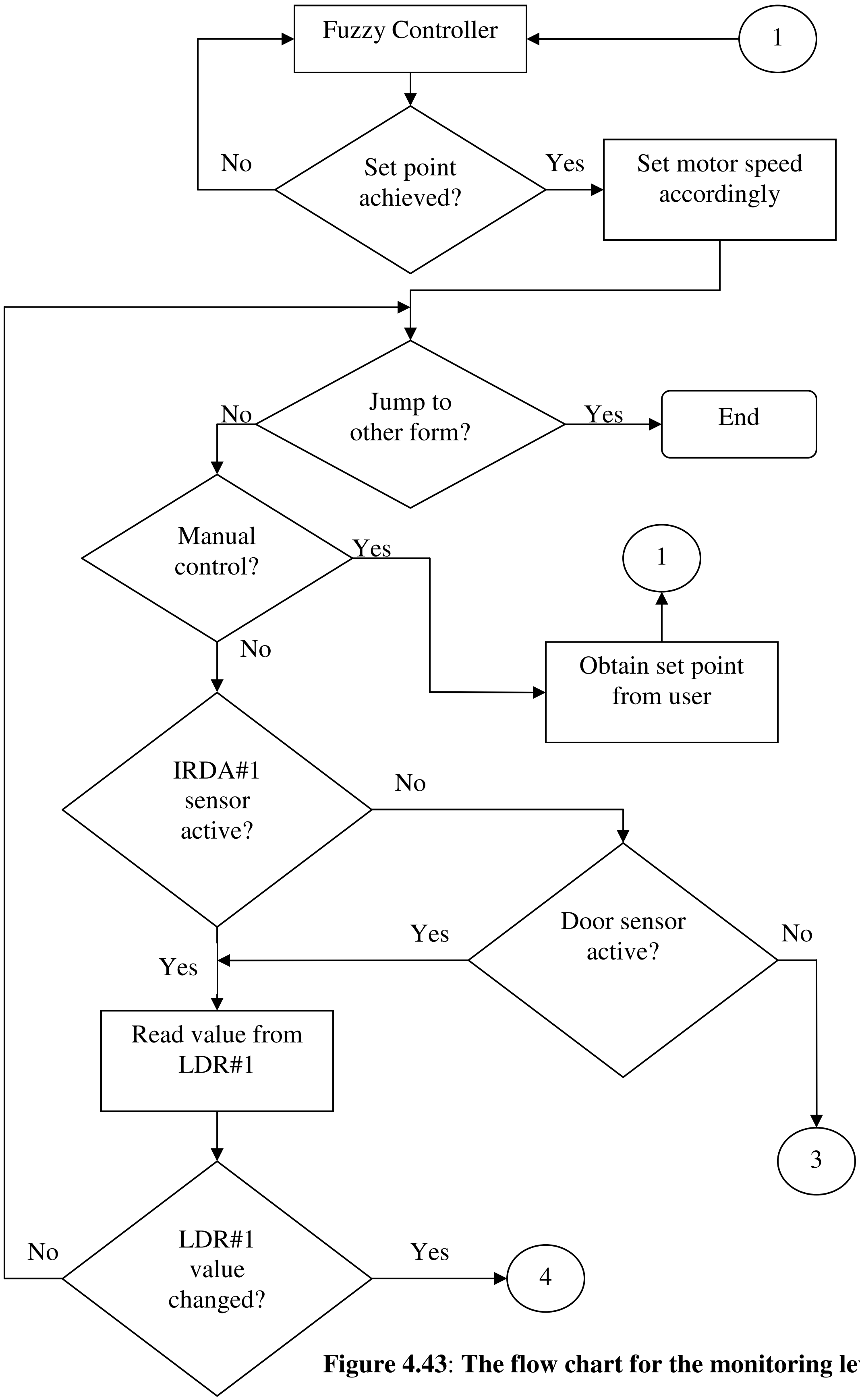


Figure 4.43: **The flow chart for the monitoring level system**

4.6 Neural Network System

The techniques proposed in this section is advancement to the method describe in Section 4.5 where fuzzy logic and motion detector is used to determine on/off of a system. With that way of implementation, the on/off of devices is based on the motion detector and the system do not have the ability to learn and unable to switch on the devices before the present of people.

In this section, neural network approach is proposed where this enables the system to learn the different behavior of different people and switch on the device a bit earlier before the resident enter to the room. The idea on mapping the inputs to the neural network is gained through literature review. Using Multilayer Neural Network is another approach of developing an intelligent home since others are using algorithm that expanded from neural network.

4.6.1 Development of the Neural Network System

The method proposed here is the Feed forward Multilayer Neural Network with the Back propagation Algorithm. In multilayer neural network, there is an addition of a hidden layer of neuron that allows the solution of nonlinear problems and others practical applications. Feed forward is the models of ANN which indicates that the signal flows in one direction only that is from the lower layers (input) to upper layer (output). Each neuron receives a signal from the neurons in the previous layer, and each of those signals is multiplied by a separate weight value. The weighted inputs are summed, and passed through a limiting function which scales the output to a fixed range of values. The output of the limiter is then broadcast to all of the neurons in the next layer.

The home automation system is using a two-layer network where it consists of input layer, one layer of hidden neuron and an output layer. This is a supervised learning where the training patterns are provided to the ANN together with a target which is the data that collected in the database. The input layer of the neural network is the time in minutes. Time helps the system to know what patterns to be used at what time of the day. The output for the neural network is the condition of the devices (on/off). The motion of inhabitant (on/off the switch of the devices) is the target for the neural network. Time is suitable as the input here since the system that going to develop here is a system that able to learn the behavior of the resident based on the different day and different time.

The neural network used in this home automation system consists of sixty interconnected neurons in the input layer which each of the neuron representing one minute (*Min*). Sixty neurons equal to sixty minutes and this is equals to one hour. There are thirty neurons in hidden layers and one neuron in output layers. There is only one neuron in output layer because the neuron is only decided to be fired or unfired. If the device is on, then the neuron will be fired (given an output one) and if the device is off, the neuron will be unfired (give a zero). Initially, a weight (adjustable gains) is provided for each of the connection. This weight will be adapted during the training phase so that this system able to learn the task. Bias that is used to increase the signal levels in the ANN such as to improve convergence is also an input for the neural network.

Hence, the value for the parameters in the Neural Network such as the bias, number of hidden neuron and etc is get through try and error method. Hence, for the system proposed here, the values of these parameters is shown in Table 4.2 below.

Table 4.2: Parameters in neural network that control to on/off the device

Parameter	Symbol	Value
Learning rate	η	0.99
Momentum rate	α	0.1
Initialize weight	Wij	0.01
Initialize weight	Wji	-0.01
Bias value	θ	0.2
Minimum error	Emin	0.01

The learning rate determines how fast the learning process is. If the learning rate is too large, the learning process will not converge however if the learning rate is too small, the learning process will be extremely slow. Momentum rate is required to avoid the local minima. When the neural network is in training mode, there will be one input neuron activated when the real time reach the minutes that represented by the neurons. The target of the neuron which is the on/off of the switch at that particular time is applied to the output neuron as one or zero. Then when training, the signal flow through from the input through the hidden layer and giving an output.

This output is compared with the target that provided. The different between the output and the target will results an error. This error will then compare with the minimum error that acceptable (set previously when set up the system). If the error is not smaller than the acceptable value, the error will be back propagating to the system and the training continues. Every time when the information flows from the input to the output, weight is adapted. Finally when the error between output and target is smaller than the minimum error that acceptable, the learning process is stopped and the weight is finalize.

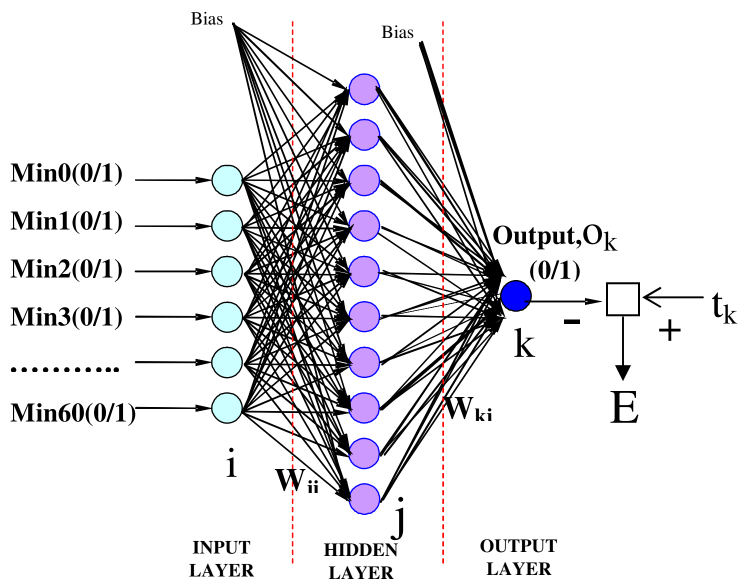


Figure 4.43: The feed forward models of a neural network that control to switch on/off the device

All the explanation above is suit to the main system that has been mentioned as to on/off the device automatically after learning. Now is the introduction to the second system which is the system that able to learn the level of fan desired for a certain temperature and also the level of brightness desired for certain brightness in room. Since both of this system is using the same concept, only the temperature system will be explained. Well, same with the first system, the feed forward multilayer neural network with back propagation algorithm is used in this system.

However, now the input is twelve neurons where it represents twelve degrees Celsius of the current temperature (*Temp*). The output of this neural network consist of 0, 0.3, 0.6 and 1 where each of these represent the level of fan desired which is from level one to level four. Since the way the neural network works is explained previously, now the way that the system learned will be discussed.

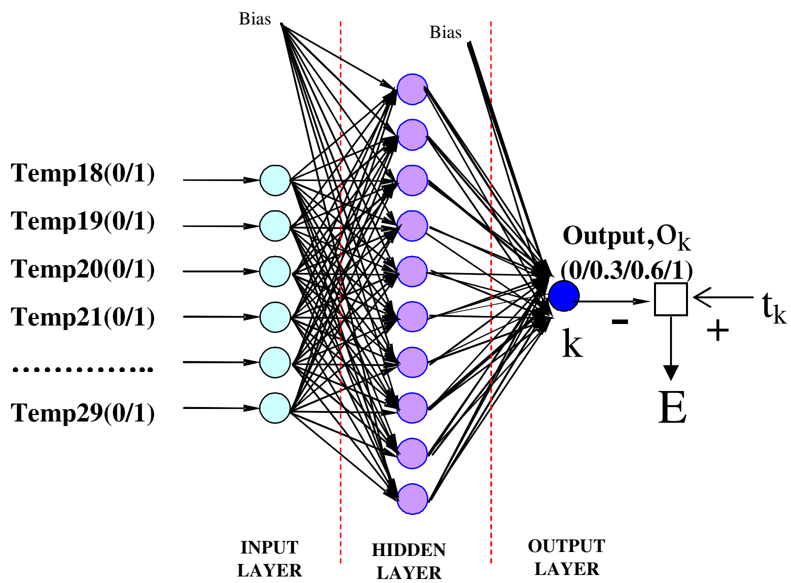


Figure 4.44: The feed forward models of a neural network that learn to adapt to level of temperature desired by resident

For an example, let say temperature with the range (18˚ – 20˚) is considered cool by *resident A* and he choose level one for the fan, temperature range (21˚-23˚) is considered normal and the *resident A* choose level two, while range (24˚ - 26˚) is considered hot by the *resident A* and he would like to choose level three, and range (27˚ - 29˚) is considered to be very hot by *resident A* and he choose to on the fan at level four. This information will be learning by the system when this resident chooses the level of fan desired upon these temperatures.

Table 4.3: Example pattern of *Resident A* in choosing level of fan desired

Room Temperature	**Feeling of *Resident A***	**Level of fan chosen**
18˚ - 20˚	Normal	Level 1
21˚ - 23˚	Hot	Level 2
24˚ - 26˚	Very	Level 3
27˚ - 29˚	Very very hot	Level 4

Then if there is *resident B* with different behavior such that he consider 18˚ to be normal and he switch on the fan at level one, (19˚-22˚) is considered hot to him and he choose level two of fan, temperature range (23˚ - 24˚) is considered very hot and *resident B* choose to on the fan at level three, and at range (25˚ - 29˚), resident B considered to be very very hot and he on the fan to the maximum which is level four. So with these data recorded, the system will learn this behavior and perform this behavior when *resident B* is in the room.

Table 4.4: Example pattern of *Resident B* in choosing level of fan desired

Room Temperature	**Feeling of *Resident B***	**Level of fan chosen**
18˚	Normal	Level 1
19˚-22˚	Hot	Level 2
23˚ - 24˚	Very hot	Level 3
25˚ - 29˚	Very very hot	Level 4

For the third system, it work as an enhance security system during the first system working. It will compare the previous behavior it learned with the current behavior of the inhabitant when the system is working. If the system does not expect its resident to be home until 5 pm on weekday and someone show up at 1 pm, it would recognize that the person is not one of the inhabitants. Then the system needs to take action by sending a signal to activate a camera and record the events in the room.

4.6.2 Developing the Database System

For this project, *MySQL database* is used to store the data and provide useful data to Neural Network algorithm.

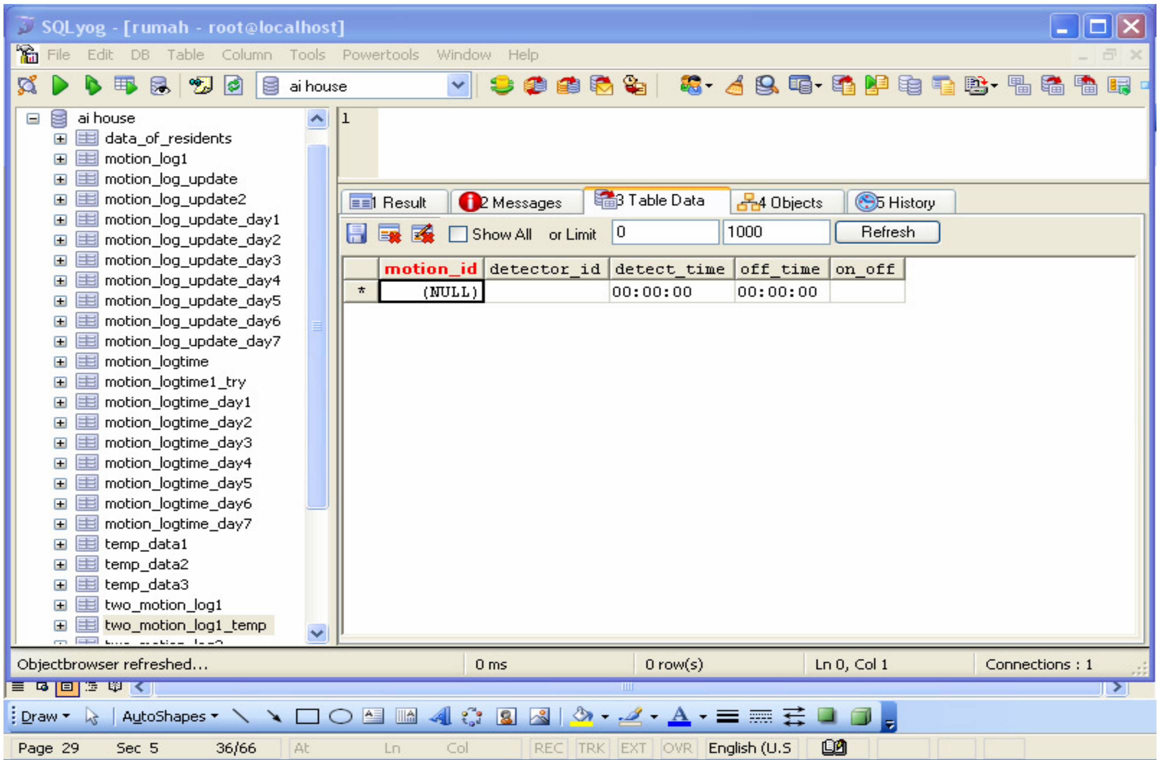


Figure 4.45: View of Table in MySQL database

The data must be collected before the system able to train. The interface for the home automation system is designed to serve as a platform to perform raw data collection for the database. Basically, elements in the database include raw data for analysis and training.

When in the testing mode, the system is working and switch on/off the device (showing on/off on the display button). At the same time, overrides to on/off the device can be done and data will be written into database if there is any override. Figure 4.46 and Figure 4.4.7 shows the way of the data collection works.

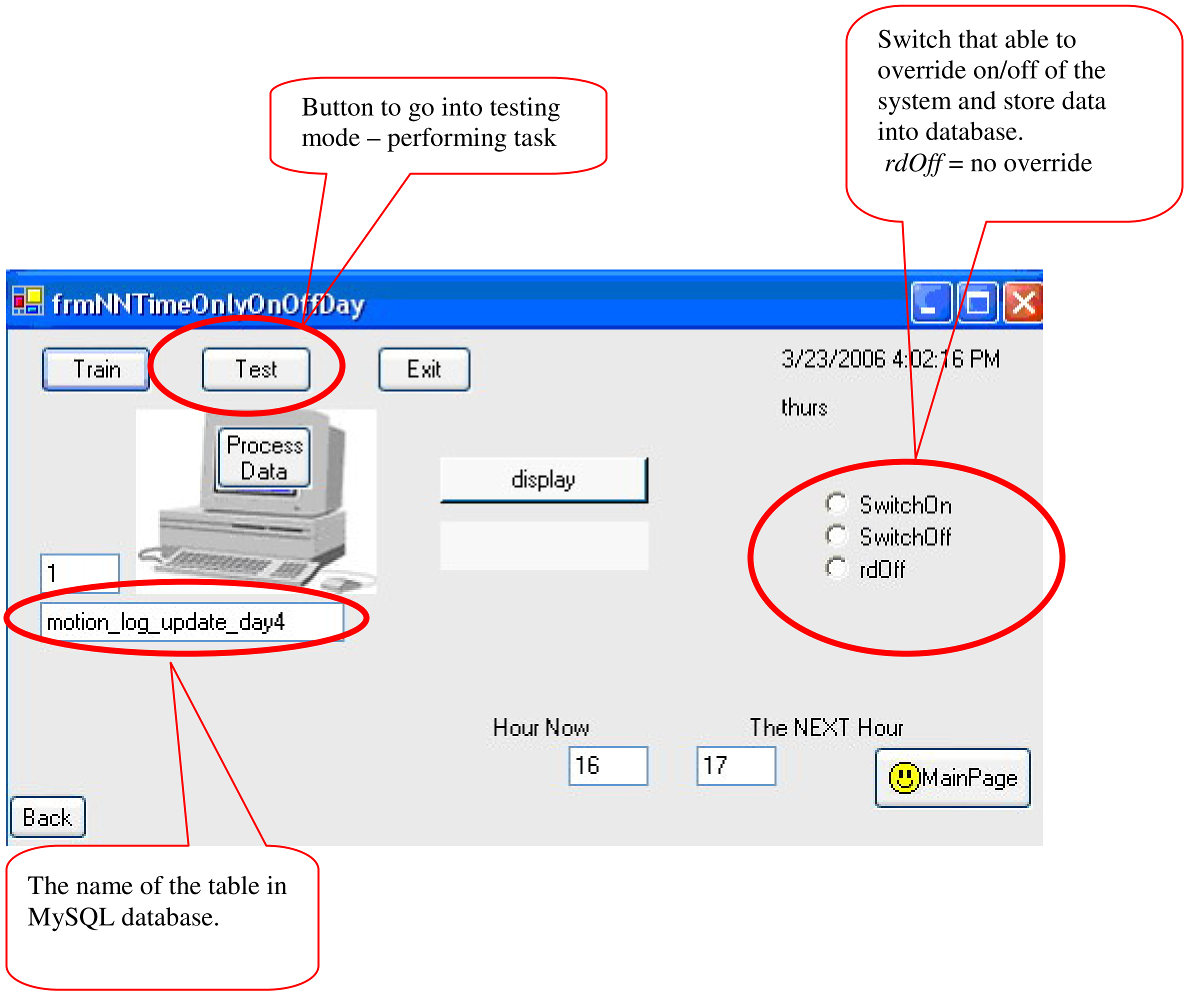


Figure 4.46: The way data collected

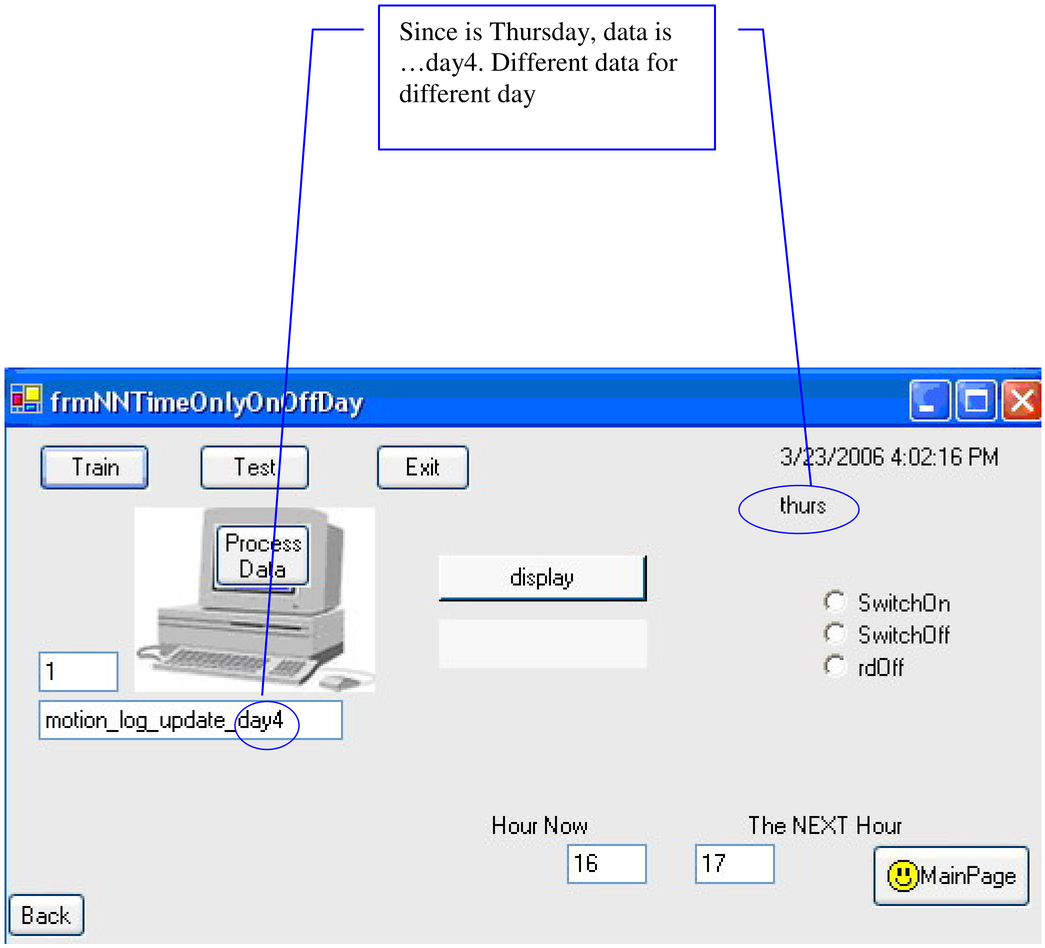


Figure 4.47: Different Table in database for different day

Anyhow, the first step to create this database is to build up the database itself. This means that to build up the tables for storing the data, declaration on type of data is needed to let the software know the type of data that will be stored.

After the time switch on/off of the devices is written into database, the data will be process. When processing, the data is analyze and break into minutes. Each minutes is determined to be one or zero (one is ON and zero is OFF). Then, this will become the target of neural network. The neural network will learn to be near to the target. After training, weight will be adapted. The weight is given a name and kept in bin folder in the program. This weight will be automatically generate and further updated by the program after training. It is actually transparent to the user of this system.

4.6.3 Software Programming

Visual Basic .Net is used to create the GUI and implement the learning algorithm. There are ten window forms in this system. Some important main forms will be further discussed here. Figure 4.48 shows the flow of the complete system in this project.

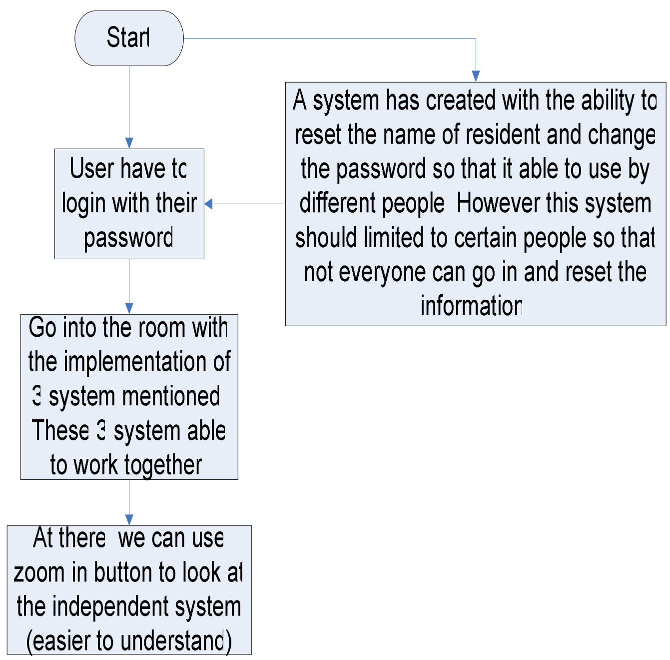


Figure 4.48: The flow of the complete system developed

4.6.3.1 Form Adapt to Brightness Desired

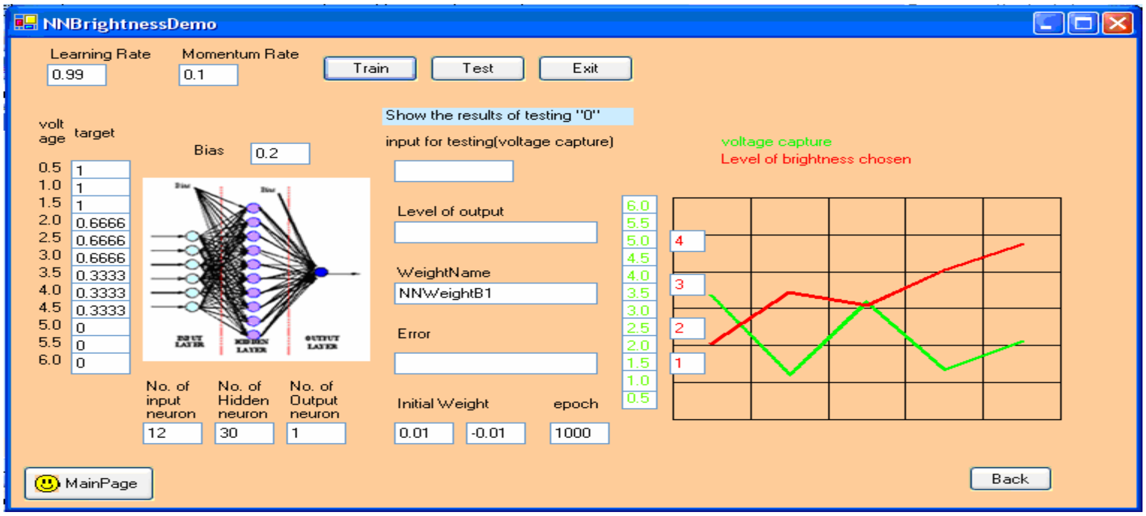


Figure 4.49: Form Adapt to Brightness Desired

4.6.3.2 Form Adapt to Temperature Desired

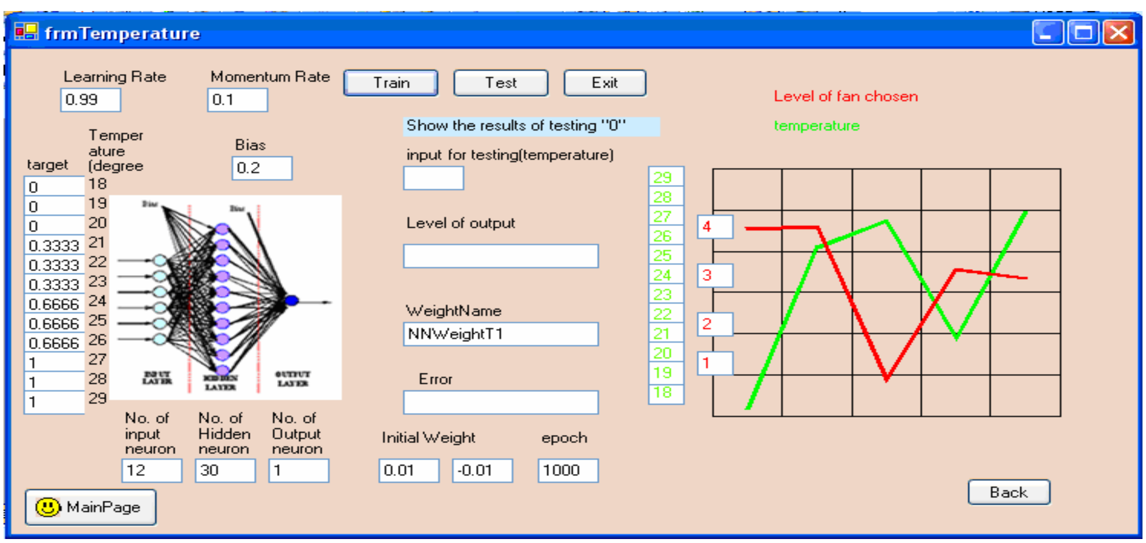


Figure 4.50 Form Adapt to Temperature Desired

The two forms below, *Figure 4.14* and *figure 4.15*, shows the different output for the same condition (*temperature*). This happened when after learning; the system able to give a different output depends on the weight adapted. Different level of fan chosen in the graph shows the different patterns desired by different people.

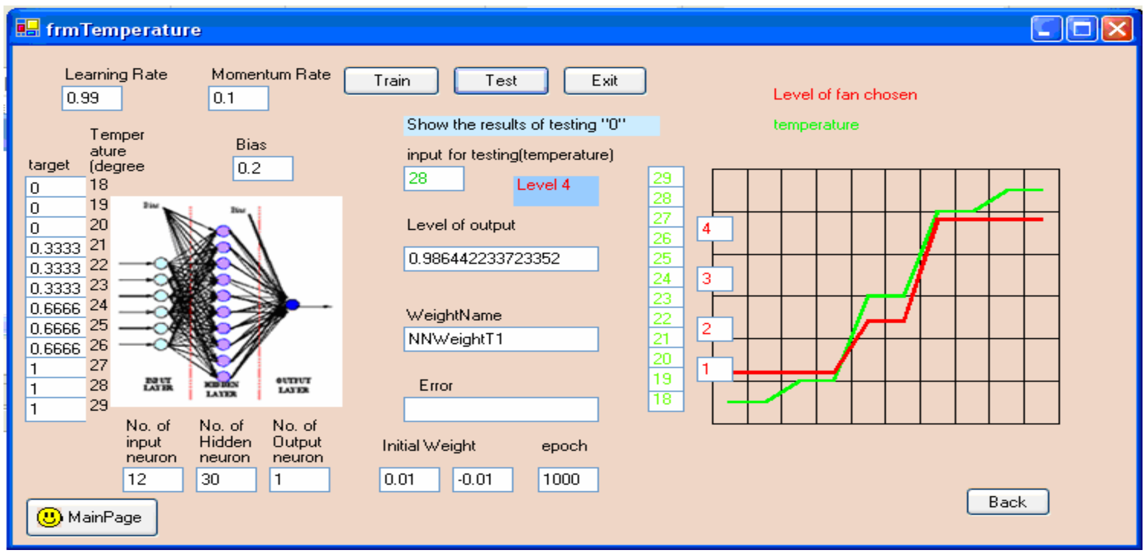


Figure 4.51: The pattern of output for *resident A*

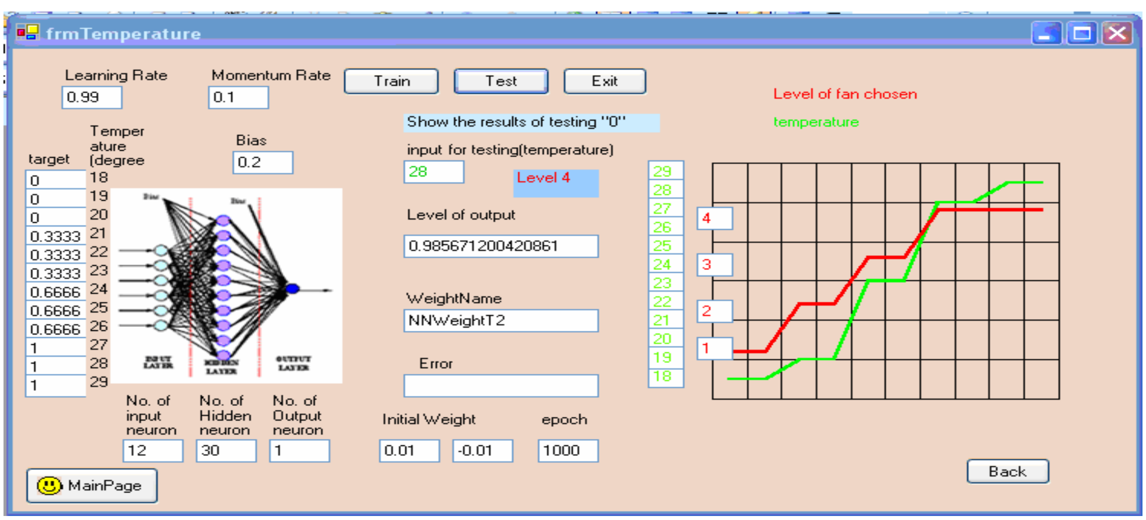


Figure 4.52: The pattern of output for *resident B*

4.6.3.3 Form Security System in Two Rooms

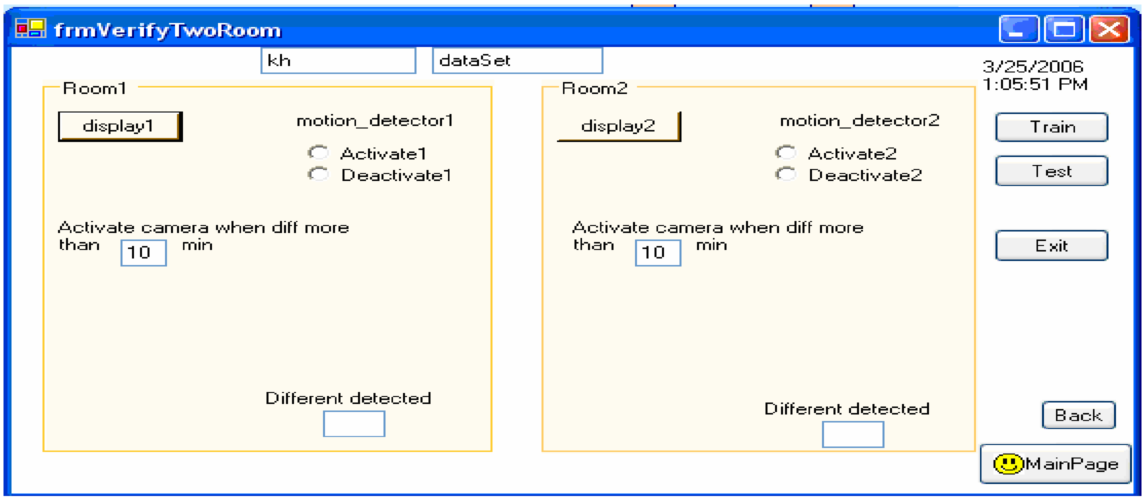


Figure 4.53: Form Security Systems in Two Rooms

CHAPTER 5

RESULT AND DISCUSSION

5.1 CAIRO - I Home Prototype

The I-Home prototype installed in CAIRO premise shows the successful outcome and development work by the research team on the Intelligent and Smart Home project. It is envisioned as the by-product of pervasive computing and the availability of smart computer technology. I-Home gives complete control over the controls, access, security, automation, and energy savings. Controls over these core elements provides the foundation of a total smart home/office solution, giving the resident of the property combined benefits of security, convenience, lifestyle enhancement and energy saving benefits simultaneously.

The beauty of the I-Home system is the fully flexible modular system which can be installed in both new and existing homes and offices. Plus, it is an Ethernet-based system which is rapidly developed and supported nowadays. It is always easy to plan, expand or change and installed. Status of given function can be controlled and ready anywhere on the network by several components simultaneously and it is easy to add new components to a function address or re-route a function.

The possibility of using existing network system can facilitate the installation instantly. At the centre of the system is the Master Controller System which is a central unit that contains a micro-controller that performs the desired function. The controller can be located anywhere in the installation and each device is configured just from the web. Most of the existing security products can be incorporated into the system. This system is exceptionally easy to install and configure and is based on reliable bus system. The flexibility of the I-Home makes it more attractive than other systems and the fact it wired system gives it total reliability

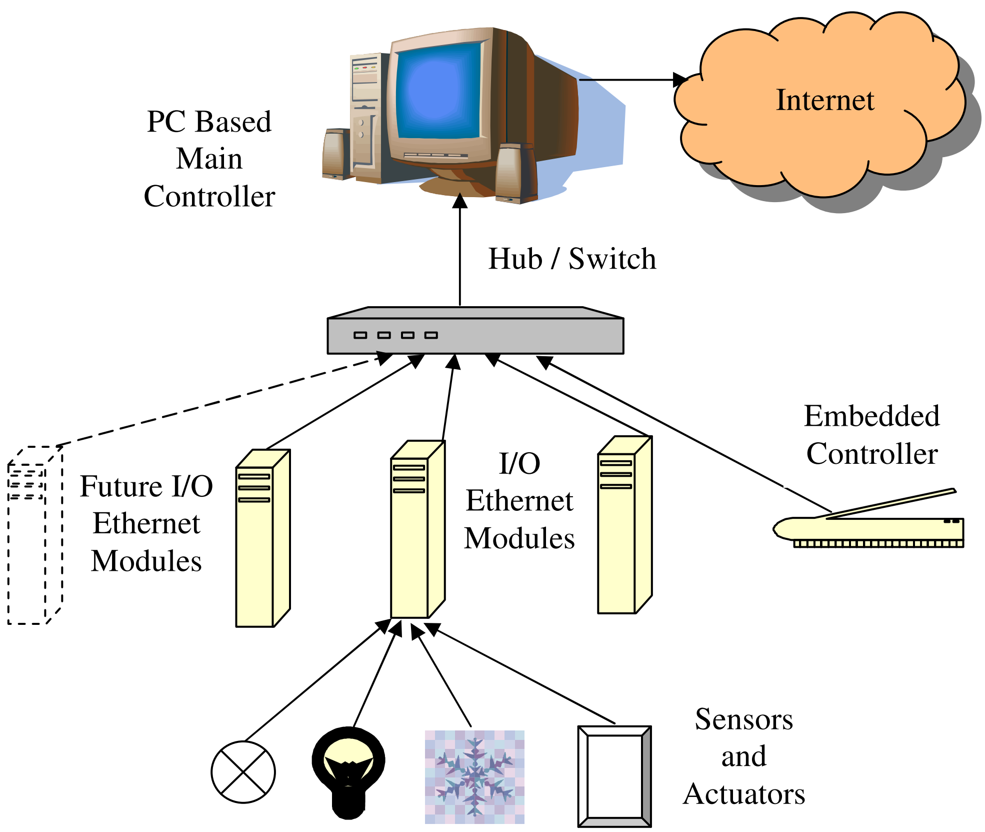


Figure 5.1: The layout of I-Home system

The user interface for I-home is very interactive and friendly. All important information is displayed in the main panel which also includes the plan layout and animation of device status. For configuration of modules and devices, the sub panel is located in the tree directory form.

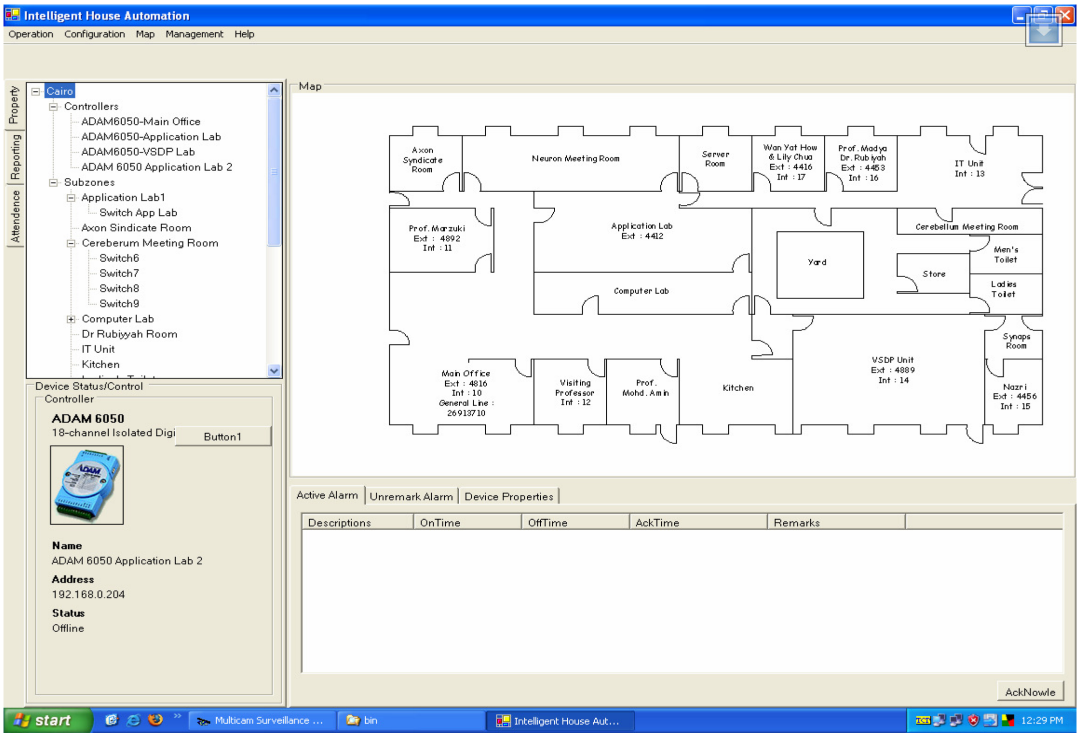


Figure 5.2: The main panel of I-Home system

The available features for configuration are:

a. I/O module configuration
b. Serial I/O module configuration
c. User and Access configuration
d. Security system configuration
e. Energy Saving configuration
f. Fire alarm configuration
g. Surveillance camera configuration

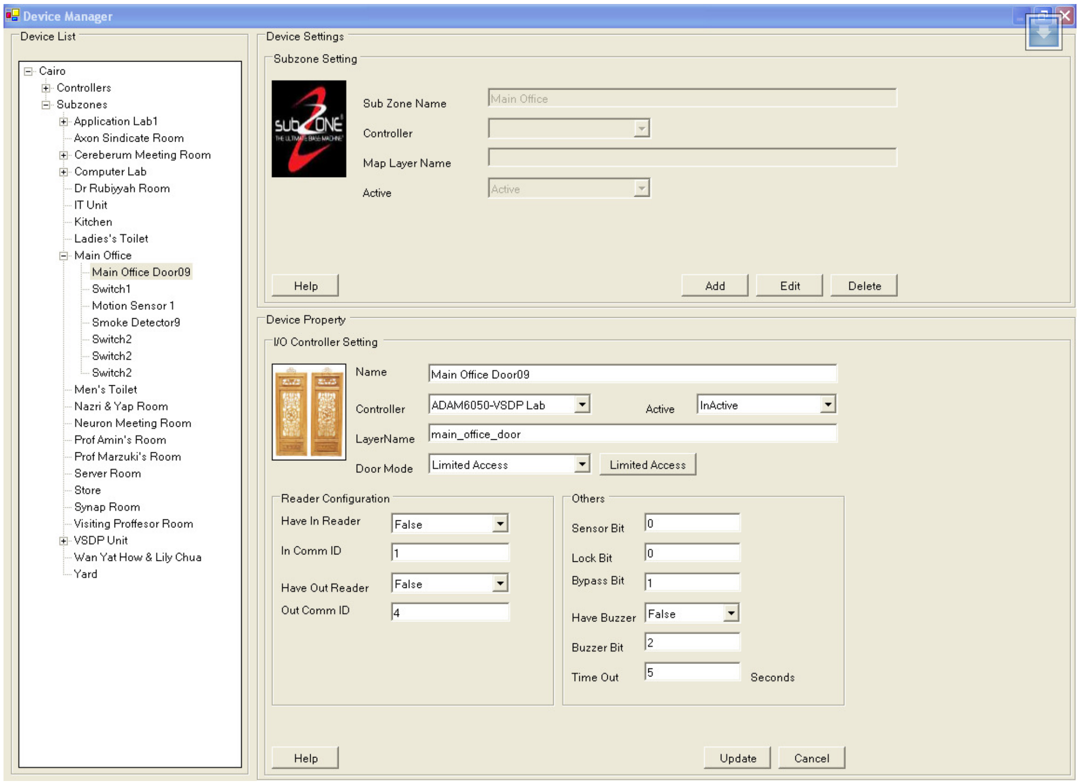


Figure 5.3: Panel for Door Control Setting

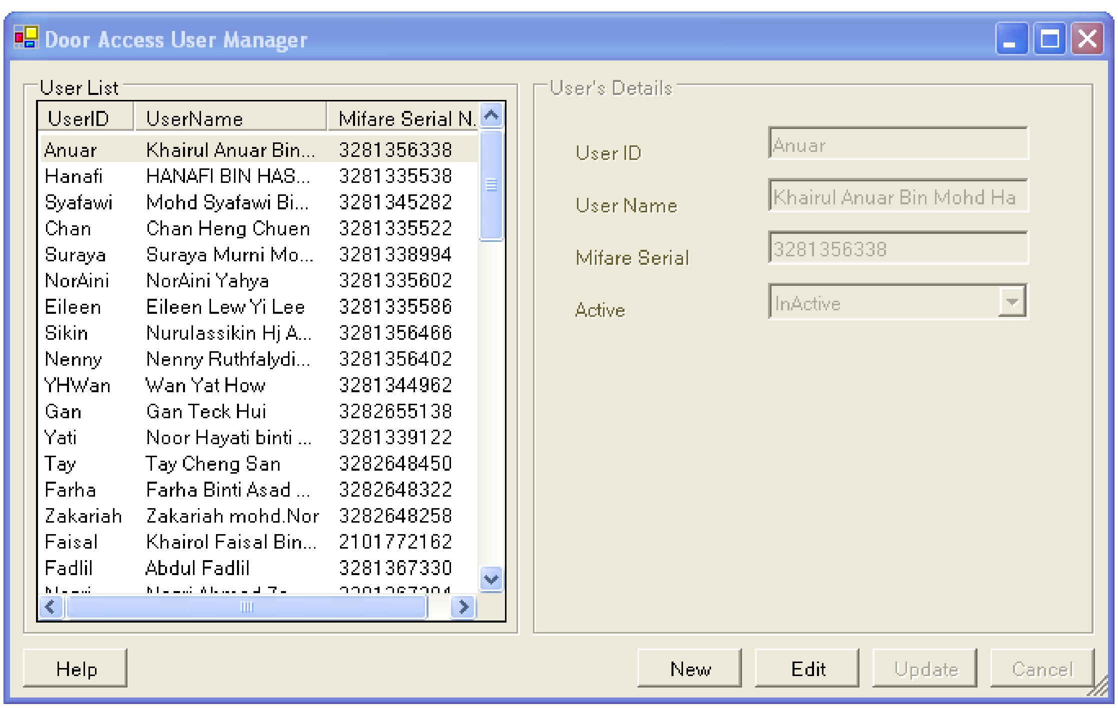


Figure 5.4: Panel lists of Door Access User

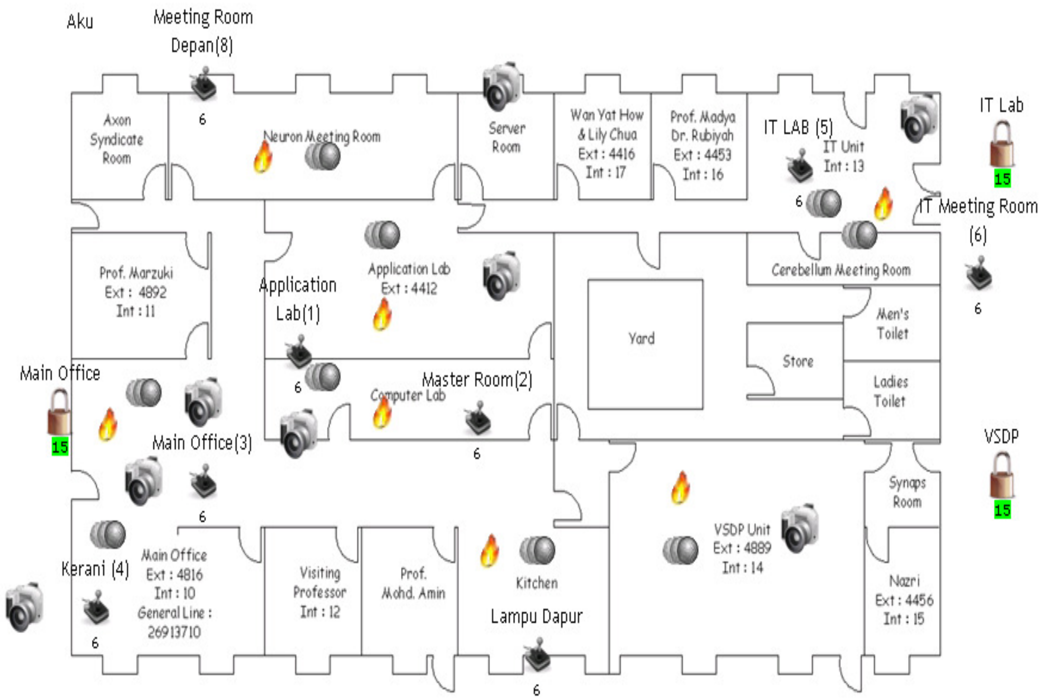


Figure 5.5: The SCADA animation of main panel

Figure 5.6: Embedded Controller with Ethernet I/O modules

Figure 5.7: Mifare Card Reader for door access control

Figure 5.8: Dome Passive Infrared Sensor (PIR) and smoke detector

Figure 5.9: Magnetic Door Sensor and Magnetic Lock

User can access the system through web browser and to monitor and control some application in the premise remotely, such as lighting, air conditioning, and door access. Also I-Home system is also equipped with surveillance cameras for user to check the premise visually using web browser. Management can also check staff attendance instantly or generate attendance report from the I-Home database. The other valued feature of the I-Home system is energy saving where the controlled devices will active only during occupancy. The fire alarm is always in alert mode and the action is configured to turn on siren and unlock all doors for emergency exit. The burglar alarm system can be activated manually of scheduled at predetermined time.

5.2 Intelligent Home System and Centralized Control System

The system that using fuzzy logic and expert system solution had been successfully developed which are the intelligent home system and also the centralized control system. However the result is only proven in simulation scale with a prototype of a house is built to replicate the real environment. This technique is not integrated yet in I-Home system. Basically the centralized control system is developed to show the comparison of the two systems created. However the centralized control system has the function of letting the user controls the house lightings and fans from a personal computer. The house model and its layout is shown in Figure 5.10 and 5.11.

Figure 5.10: The house model (angle view)

Figure 5.11: The house model (top view without roof)

In the intelligent system, everything will be automated and fuzzy controller is used to control the brightness of the light. Besides that, the fan speed is also adjusted by the system based on the current temperature. This intelligent system will be activated when it senses that there are presences of people in the room. Then it will automatically adjust the brightness of the light in the house based on the ambient brightness outside. When it has achieved that then it will adjust the fan accordingly. So whenever the outside brightness changes the inside brightness will change too. When the system detected that nobody is present then it will shut down the light and fan. The main panel for the intelligent system prototype is shown in Figure 5.12 below.

Figure 5.12: Panel for Intelligent House prototype

In fuzzy logic mode, no input is needed from the user. The system will automatically adjust the fan and light accordingly when there is someone presence. Besides that a fuzzy rule is shown to let the user knows which is rule is fired when the fuzzy controller is active. For example when the system calculated that the error is negative and rate of change of error is negative too then the fuzzy rule will highlight the label “P” to show that this rule is fired.

However if the user does not prefer the light and fan the system adjusted, he/she can overwrite the system with manual control. In the manual control mode the user gets to input the desired brightness and fan power. These desired inputs can be keyed in the respective textbox located beside the blue color labels. In this manual mode it is almost the same as centralized control system but in this form fuzzy controller is used to adjust the desired output whereas in the centralized control system direct control is used. Lastly, the "ALERT" label will change its color to red when there is a presence on the roof to alert the user.

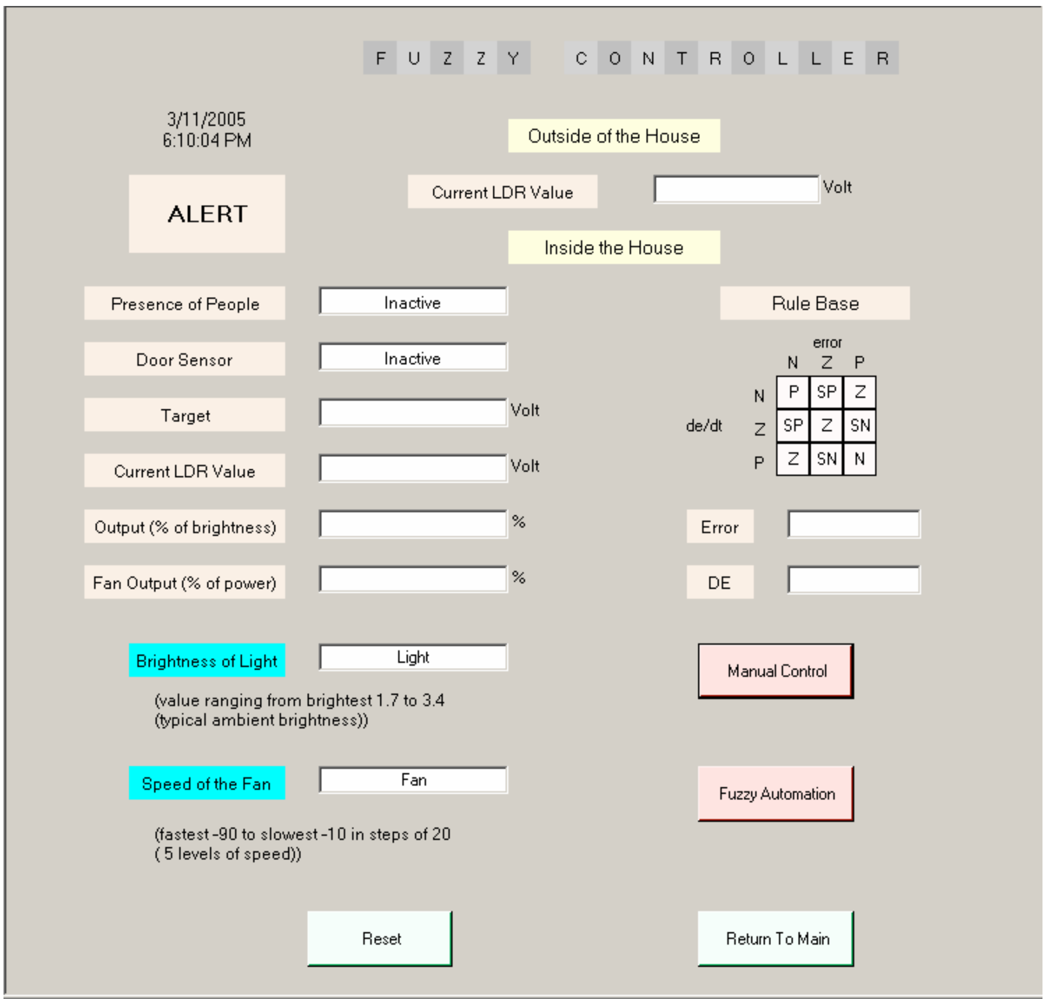


Figure 5.13: Fuzzy controller panel

In centralized control, everything will be handed over to the user. The user has the power to control everything in the house through this GUI. The user gets to adjust the speed of the fan and also the light in the living room. The fan has five adjustable speeds and the light has six adjustable bright nesses. The user can adjust the speed of the fan and brightness of the light from this form. Whenever the user presses “Speed 1” the fan in the house model will be running at the lowest speed and the status textbox below the fan label will display the current speed. This goes the same when the user changes the speed. This concept also applies in the light controlling. Hence whenever the user presses the “Bright 4” button the LED in the house model will be providing the environment with the specified brightness and the label will state the current brightness is used.

5.3 Intelligent Home System and Adaptive System

The system as stated in the objectives had been successfully developed which is the intelligent home system using Neural Network. In the intelligent system, everything will be automated and the control of home activities is invisible to the resident. Neural network is used to control the brightness of the light. Besides that, the fan speed is also adjusted by the system based on the current temperature. This intelligent system will be activated when the time that it learned to switch the device on/off is reached. Then, this system will automatically adjust the brightness of the light in the house based on the ambient brightness outside. At the same time, the level of fan speed will be adjusted based on current temperature. So, whenever the outside brightness changes, the brightness of the light will be changed. The same condition happened for fan where the changed of temperature will results in the change of speed of fan.

However the result is only proven in simulation environment with manually generated data to replicate real environment. This technique is not integrated yet in i-Home system. The main page in Figure 5.14 shows once the system started. It allows resident log in to access the system. Next, Figure 5.15 shows the integration of three systems which included the system that *Control to switch ON/OFF the device*, *System that Control the Brightness and Temperature* and also the *System for Security Purpose*.

Once TEST button is clicked, all three systems will be working.

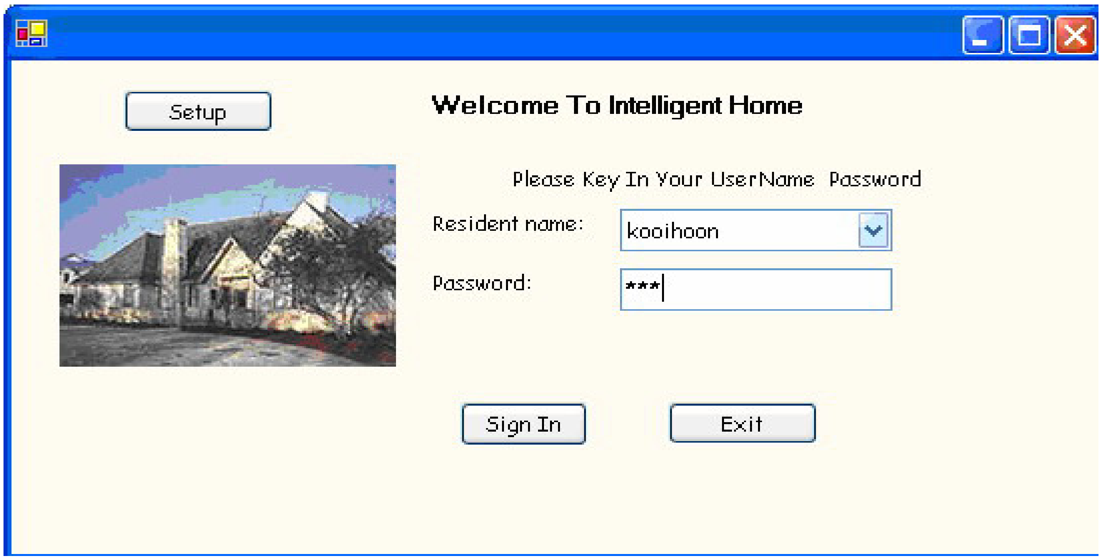


Figure 5.14: Form Log In

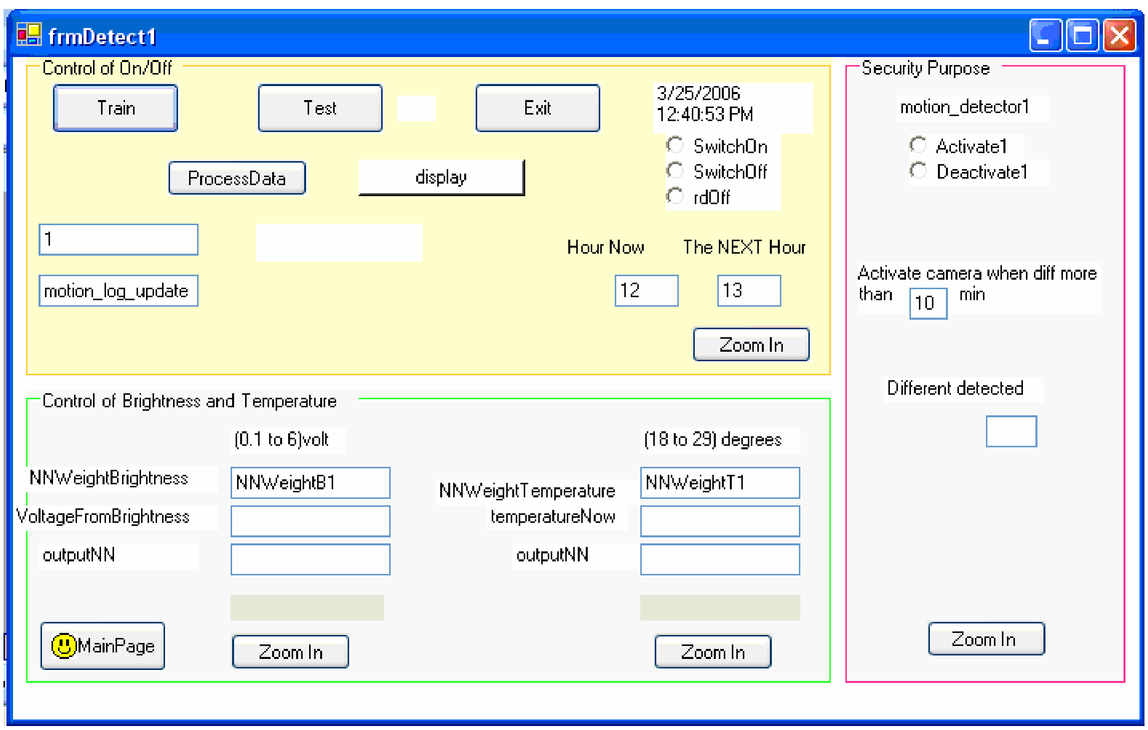


Figure 5.15: Panel Room 1

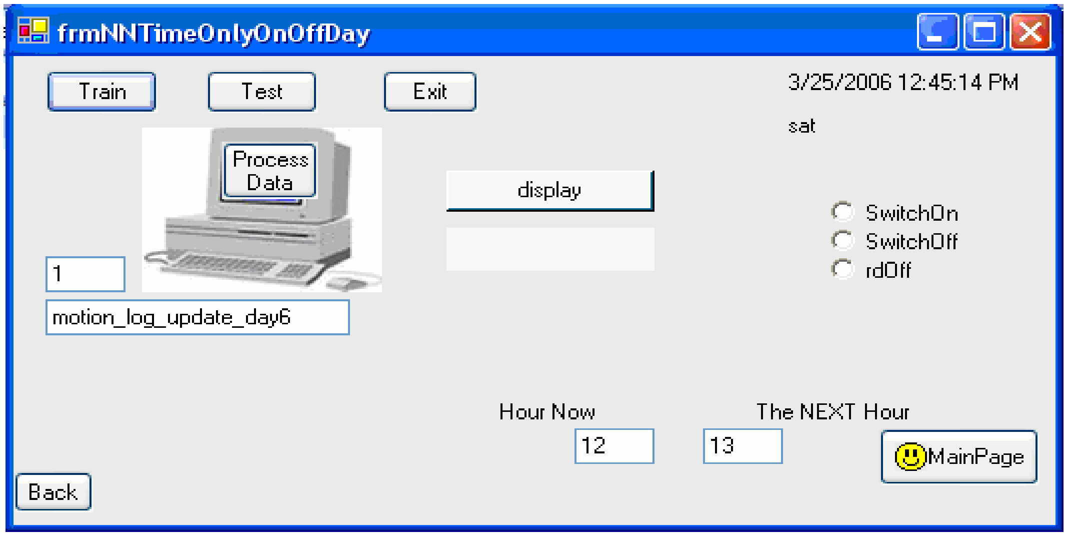


Figure 5.16: Form Control to ON/OFF the Device

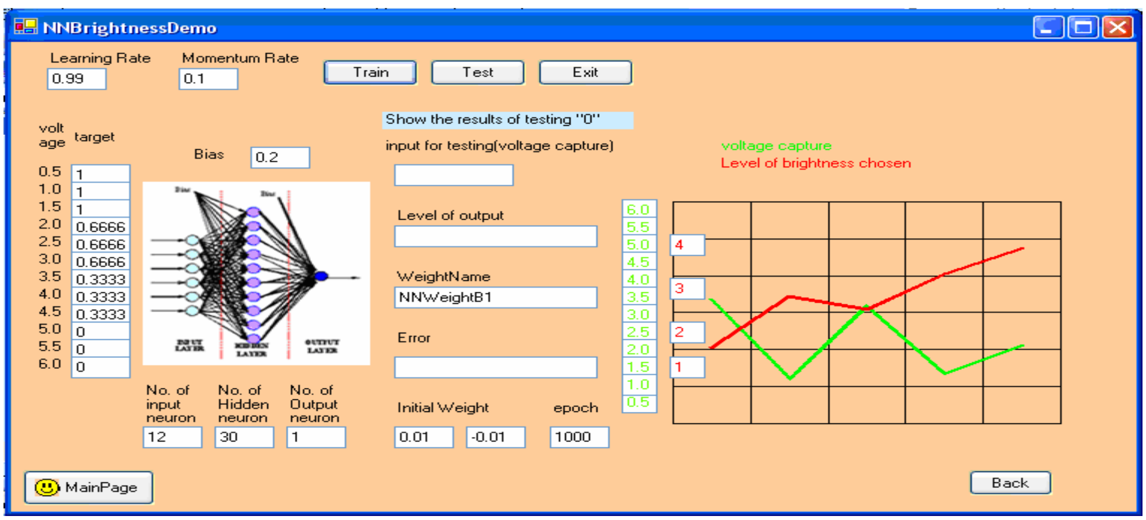


Figure 5.17: Form Adapt to Brightness Desired

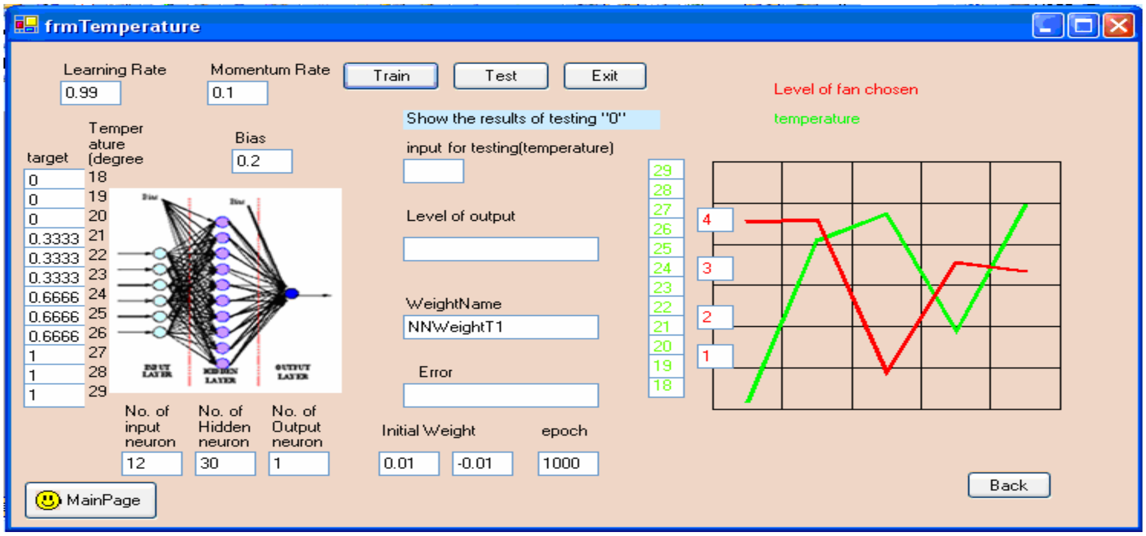


Figure 5.18 Adapt to Temperature Desired

The two forms below, Figure 5.19 and Figure 5.20, shows the different output for the same condition (*temperature*). This happened when after learning; the system able to give a different output depends on the weight adapted. Different level of fan chosen in the graph shows the different patterns desired by different people**.**

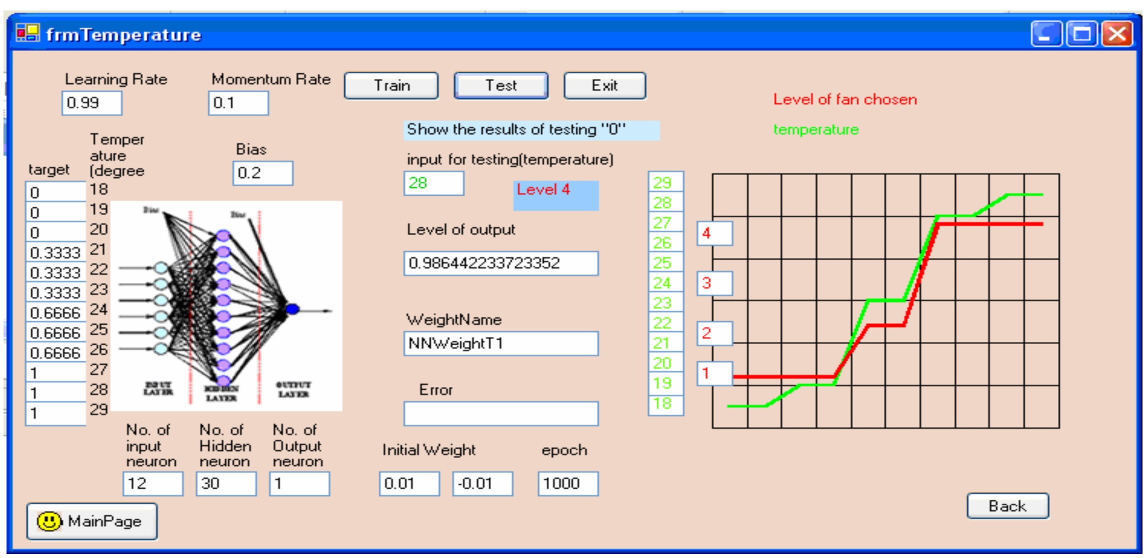


Figure 5.19: The pattern of output for *resident A*

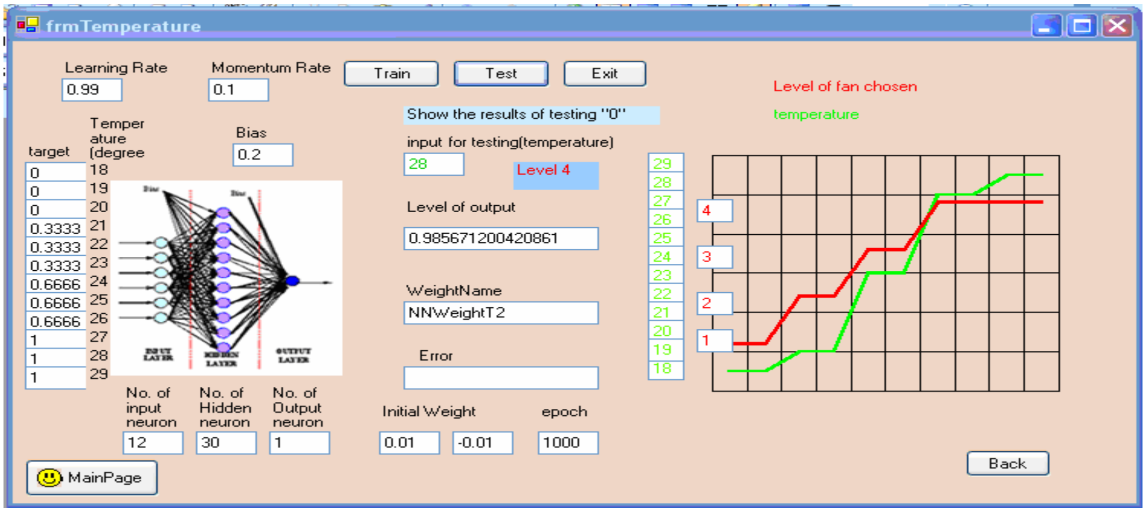


Figure 5.20: The pattern of output for *resident B*

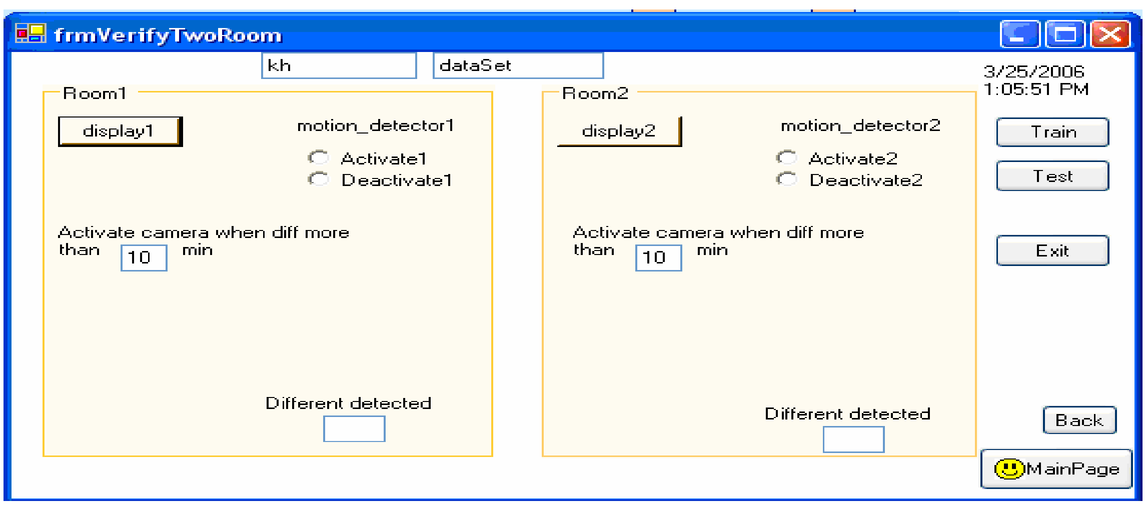


Figure 5.21: Form Security System in Two Rooms

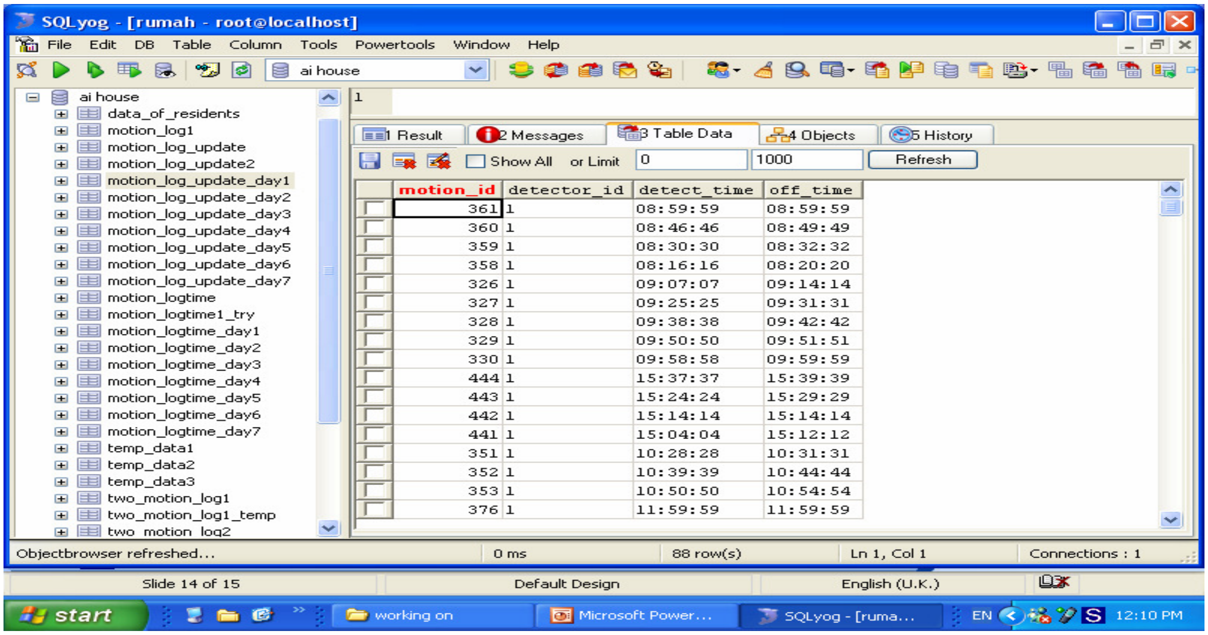


Figure 5.22: The database of table data_of_residents

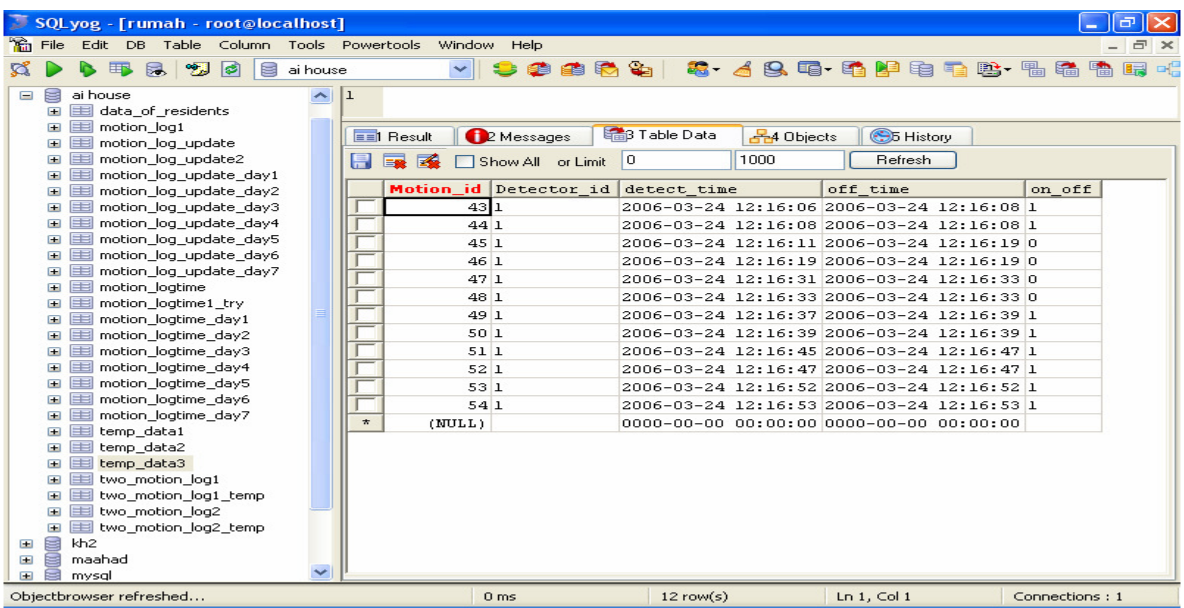


Figure 5.23: The database of table motion_log_update_day1. (Processed data recorded on Monday)

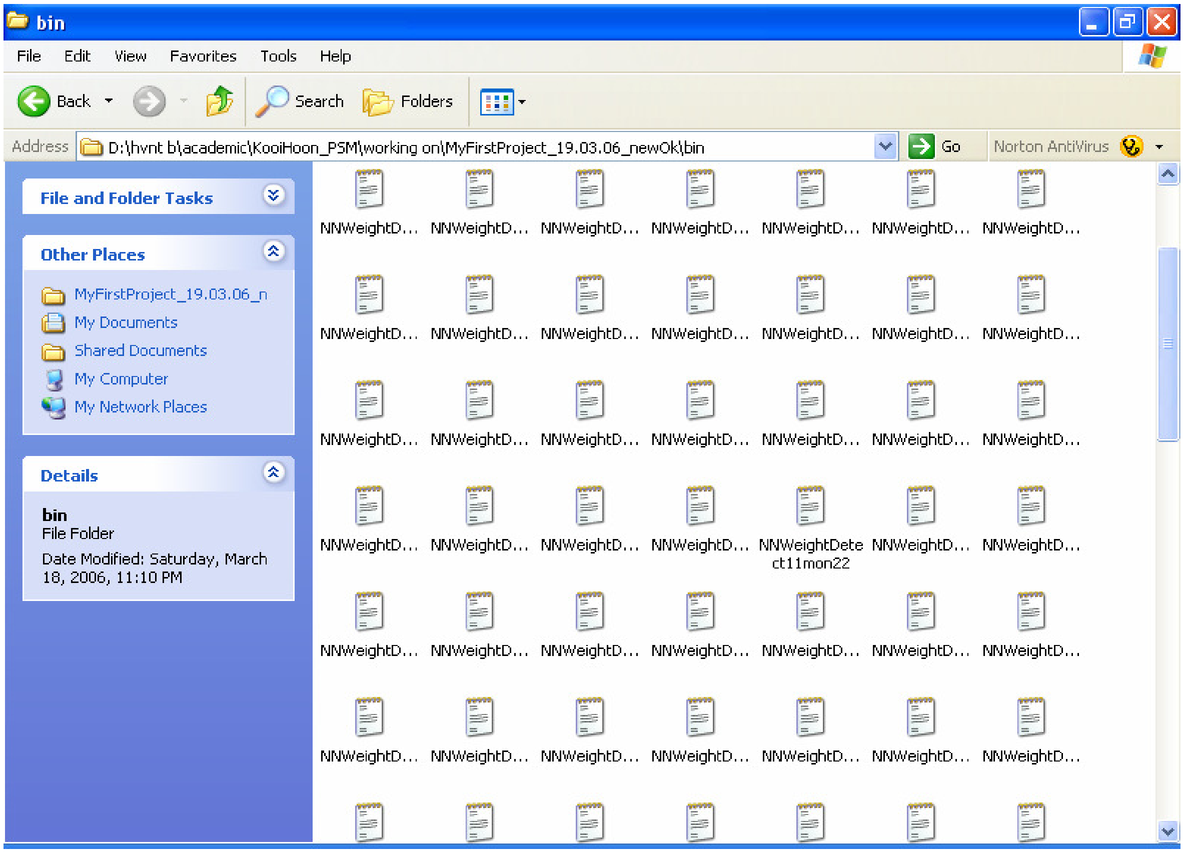


Figure 5.24: Examples of weight adapted that kept in bin folders of the project. Each weight represents a different pattern of lifestyle.

The systems developed able to learn and perform as what it learns after training. The system able learns to switch on/off the device based on the time that it learned from a particular resident. Besides that, the system able to learn the level of brightness and temperature desired by the resident based on current temperature and current brightness with the level chosen by the resident.

CHAPTER 6

CONCLUSIONS AND RECOMENDATION

6.1 Introduction

Under this IRPA project, the main objectives of this project is to design an intelligent home automation system that can provide home and office owners with an integrated environment, intelligent devices, ease-of-use and safety environment to their home. This objective also can be categorized into two main parts which are:

iii. To develop master software based on Artificial Intelligent technique which is capable of integrated remote control and monitoring of appliances and devices via the internet, record events and providing security.

iv. To design intelligent sensoring system using AI techniques such as fuzzy logic and neural network to overcome false alarms occurrence as well as to provide easy living and power savings.

6.2 Achievements and Benefits

The I-Home system project already met to the main objectives as stated above whereby owners may have this system attach or fix to their house. Owners can feel much more comfortable even though they are not at home. They still can monitor and check the situation of their house, using the technology that we have offered for them. The knowledge that has been gained by the team are:

- Applying Artificial Intelligence techniques which are Neural Network and Fuzzy Logic to the system. With this combination of method, a complete security I-Home system is successfully developed.

- Knowledge in integrating mechanical and electrical parts and components together.

- Applying knowledge using various kind of technology which are AJAX, web service and equipments such as cameras, modem and various kind of sensor such as smoke sensor and card reader.

From the results in Chapter 5, it shows that the objectives of this project are achieved. Firstly a database that able to record the interaction of resident and provide data to the system is successfully developed. The database has tables that able to store different data for different day and time. So, this database played an equally important role with the home automation system to enable the system function properly.

Part of the experiment is done in simulation and controlled environment. The real environment constraints such as birds, insects and forces of nature are neglected. It is important to consider these constraints because these will affect the sensors placed outside of the house. Hence it is also essential to choose the appropriate place to place sensors such as the LDR sensor to avoid these disturbances. In this project these disturbances do not surface because the sensor is mounted to a house model and not to the real house exposed to the real environment.

It is undeniable that artificial intelligence approaches such as expert system and fuzzy logic are useful in human life. Expert system can be used to replace experts to manage a system, for instance to replace a human to manage their house. Moreover expert system does not have human weakness such as absent-minded. Fuzzy logic too is good in controlling a system. It can achieve its set point in a very fast response time. Hence it is useful in controlling and managing a system so that the system does not overshoot its set point and causes unstable conditions. An additional system that able to detect the different behavior exhibit is developed. This system able to alert and take action when detects the different. The different give a suspicion that the person in the house is actually an intruder and not the registered resident.

With this project it is true that artificial intelligence knowledge can be used to develop intelligent home system. Perhaps further research need to be conducted before it is actually applied in human real life. Hopefully this project will at least bring up some ideas to the future designer.

6.3 Future Suggestions

Almost all developed system, there might be a few upgrading that can be done to the system, same as I-Home. There are a few suggestions on Linux embedded system and surveillance system. For Linux embedded system, below are the suggestions:-

- I2C RTC
- Text to Speech (Festival/Flite)
- Speech to Text (Sphinx)
- Text manipulation program (Megahal)
- Bluetooth as RFID replacement
- Mobile agent for multi-controller system

For Surveillance system, the suggestion will be 3GP video format for low bandwidth video (3G phones) and also Linux embedded controller will be using in robotic application.

In the intelligent part, more rules can be added at the expert system which will make the intelligent system even more robust. The security for the system created can be tightening by creating a log-in form in order to prevent outsider from logging into the house system. This will definitely prevent uncontrolled access to the house system. Moreover a form for guest viewing purpose only also can be created in order to let the user knows the system implemented in the house.

The behavior of different people is different for different day. Here, the solution proposed is seven set of data are used for seven different days in a week. These seven set of data represent the data from Monday to Sunday. So this system is able to learn the life patterns of the resident and at the same time they able to differentiate the data by the day.

The system to switch on/off the device, the system to control the brightness and also the system to control the temperature are three different systems. Each of this system has their own neural network. However, these three systems are placed in the same room so that these systems work at the same time. So, with this way of implementation, neglect of time will never be a problem.

Since neural network is able to learn a pattern, when train the neural network in the system, different pattern shall be differentiate. So when considering that the lifestyle of the resident is different for different day, table of data that provided is different. Thus, with this way of implementation, different pattern is learned. So, for future implementation, if there is a different pattern traced, different table of data can be provided.

In conclusion, it is true that intelligent home system do help human in managing their homes. However this is only true in theory and this system is yet to be implemented in the real world applications where many other constraints exist. For this moment, the system developed is using simulation data only. This intelligent solution will be implemented in CAIRO, I-Home to test it on real application.

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